ANALYSIS OF TENSILE TEST DATA

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May 25, 1995

This papers presents some analysis and comment on the December, 1992 tensile tests of the Kevlar fabric used in making the 71" vacuum windows for KTEV. The main goal of the test was to determine the clamping force needed to hold the window by comparing tensile tests of samples of the material in grippers modeled like the actual design flanges. A secondary goal would have been to look for the maximum tensile strength of the material. Samples were tested with the fibers on a 45 degree angle to the axis of the force to understand the strength of the weave better. The Instron testing machine in the Materials Development Lab was used for these tests.

Calculations showed that the minimum force the clamping has to support is 6845 pounds force. The tests showed that 250 ft-lbs of torque on the flange bolts would be able to support the needed force. Nine tests were done at 250 ft-lbs of torque with the flanges exactly as the final design and all passed the clamping test. See the attached spreadsheet. The percent elongation at failure of the fabric sample was found to be 50% higher than the published data from DuPont for Kevlar fibers alone. This discrepancy can be explained by the fact that for our tests the fabric does not strain at the same rate as single fibers. The extra length of fibers because of the weave makes the simple measurement of sample length only an approximation which could be in error by as much as 50%.

The spreadsheet also calculates the load per inch of fabric to compare with the published data of the fabric manufacturer. The manufacturer uses ASTM D-1682 to test for breaking loads and elongation of fabrics. We have no elongation figures for the fabric from the manufacturer but they do publish the strength. Their number for this fabric is 1800 pounds force per inch of fabric. If our data set is analyzed the measured number is 966 pounds per inch. The difference is in the samples and tests. In ASTM D-1682 a one inch wide sample is put between grippers that typically grip harder as the tensile force rises and does not require bolts to supply clamping force. The clamping system in our tests does not supply the same level of grip on the samples. In our sample testing scheme what happens is that all of the fibers in the areas of the bolts (50% of the total sample) are not gripped hard enough to test to failure. The aluminum ring is meant to distribute the load of clamping to the areas between the bolts but that force is limited to the amount provided by a specific level of bolt torque. At some level of testing force the fibers can still slip past the aluminum ring. The best example we have of that is test number 21 which didn't use the aluminum o-ring but used the entire flange area for clamping. In that sample it is clear that only 1/2 of the fibers are participating in the test. If the number of LOADED fibers is compared then our tests give a load per inch of 1932 pounds per inch which is comparable to the published data for the fabric. We have kept many of the samples for later visual inspection.

The success of these tests has been indicated by the fact that in none of the later pressure or creep tests has any window shown a tendency to pull out from between the flanges. That was the principal reason for the tests. The secondary reason of measuring the strength of the fabric has show results in agreement with the published values of the manufacturer.

The conclusions above for the 1992 tests are also supported by the July, 1993 testing. The major difference in the two rounds of tests is that in the second round of tests epoxy was used to better bind the fabric into a more continuous sample, and minimize the effects of the short fibers in the bolt areas. The epoxy was successful in that as seen by the universally higher failure loads in the second set of samples. All of the windows in later pressure testing have been made with the epoxy bond on the circumference.

Kevlar tensile test results				
Test Number	Strain at	Maximum		
	Failure	Load		
	(inches)	lbs force		
9	0.52	7900		
10	0.47	8100		
12	0.47	11300		
13	0.47	10650		
14	0.54	9900		
15	0.5	9010		
16	0.49	8500		
17	0.41	10210		
18	0.42	11150		
Average of tests	0.47	9525		
Length of test samples	7.964			
Percent strain at failure				
for the average of tests			5.90155701	percent
Width of sample	9.858			
Load per inch of fabric			966.220329	Lbs/in

Kevlar Window Tensile Tests

Fred Renken

12/23/92

FNAL RD/MSD Thermal Systems

ABSTRACT:

For the new KTev 1.8 m window tests were necessary to complete safety requirements and assure the window design would meet the necessary standards. Three different configurations were tensile tested to find the torque values necessary to meet requirements based on calculations. It was found that the use of an aluminum gasket increased the clamping capability but also increased damage to the window materials. Without the gasket the clamping fixture slipped at lower loads but held higher maximum loads. Tests with spacers proved that such assemblies would be very difficult to use. Increasing torques will increase the capability of flanges to hold the fixture.

INTRODUCTION:

On the new fixed beam target experiment KTev, a 1.8 m diameter vacuum chamber window will be constructed for experimentation. This window, although very like others built in the past, is much larger and so extra safety precautions and documentation is needed. The window is constructed of a kevlar fabric sheet for strength between layers of mylar for protection and vacuum seal.

Three different clamping configurations were tested. The first clamp was the same as the fixture used on previous windows with a soft alloy aluminum gasket to achieve a tight seal and account for tolerances in bulk head construction. The second was to test without the gasket, holding the window between only the two bulk heads. Steel inserts were placed in the test samples to simulate a flat bulkhead. In order to use this configuration much tighter tolerances in the bulk head construction will be necessary in order to achieve a vacuum tight seal. The third test was conducted with metal spacers between the flanges inside the window materials to assure bulkhead strength. These tests required the use of the aluminum gasket.

Several aspects of the window were examined in each test. First, would the clamping assembly itself damage the window materials beyond usefulness by compressive forces cutting through the materials. Second, at what load will the first slip or indication of failure occur. At what clamping force or torque would the necessary load be upheld. Most importantly, what maximum load can be sustained in each configuration. Finally, the overall damages and performance of the test samples used.

The window bulkhead flanges were simulated by preparing samples for a tensile test. The clamps were designed to closely simulate the real flanges with both window assembly bolts and through bolts to the vessel. (See drawing numbers 9220.832.ME-285684 and 9220.832.ME-285674) All bolts would be torqued evenly. For this test sample a minimum load of 6845 lbf would be necessary to meet calculations done in an ANSYS analysis of the window. (Attached) The tensile test provides a unidirectional load rather than an even multi-directional force as in the actual window. The actual window should therefore perform better than these tests would indicate.

Test Data

Test #	Test Speed	Weave	Torque	First Slip	Max Load	Al dim: see fig		Notes:
	in/min	degrees	ft*lbs	lbf	lbf	X	Y	
1	0.05	90	56	1010	2478	—	—	No Mylar used
2	0.075	90	83	2010	2810	0.061	0.188	
3	0.075	90	111	2600	3700	0.084	0.184	
4	0.075	90	139	3260	3900	0.079	0.201	
5	0.075	45	83	1200	2005	0.063	0.181	
6	0.075	45	111	1440	2200	0.082	0.202	
7	0.075	45	55	590	1940	0.045	0.187	
8	0.075	90	195	6550	8300	0.143	0.157	Past Full Scale on Graph
9	0.05	90	195	5400	7900	0.132	0.156	
10	0.05	90	225	6700	9100	0.139	0.153	
11	0.05	90	167	3020	5700	0.119	0.166	
12	0.05	90	250	7500	11300	0.15	0.152	
13	0.05	90	280	6800	10650	0.156	0.152	
14	0.05	90	250	6300	9900	0.167	0.156	
15	0.05	90	250	5100	9010	0.134	0.154	Strange curve and values
16	0.05	90	250	5500	8500	0.148	0.153	
17	0.05	90	250	7400	10210	0.144	0.152	New Bolts used
18	0.05	90	250	7050	11150	0.136	0.154	
19	0.05	45	250	3990	4510	0.157	0.15	
20	0.05	45	250	3700	4005	0.147	0.149	Displays Yield Curve
21	0.05	90	250	5005	13600	N/A	N/A	No Aluminum Used
22	0.05	90	250	5010	12950	N/A	N/A	No Aluminum Used
23	0.05	90	250	7300	12440	N/A	N/A	No Aluminum Used
24	0.05	90	250	5200	12810	N/A	N/A	No Aluminum Used
25	0.05	90	250	7050	8000	0.146	0.151	Al Spacers
26	0.05	90	250	5100	5900	0.132	0.156	Al Spacers
27	0.05	90	250	5800	6810	0.143	0.157	Steel Spacers
28	0.05	90	250	5700	7005	0.158	0.153	Steel Spacers
29	0.05	90	250	5210	6100	—	—	Used Al Spacers

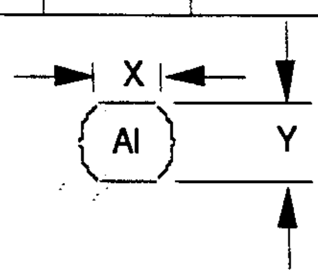


Fig 1: Aluminum Cross Section

Test Data

Test #	Test Speed	Weave	Torque	First Slip	Max Load	Al dim: see fig		Notes:
	in/min	degrees	ft*lbs	lbf	lbf	X	Y	
Al Gasket used: 250 FT*LBS Torque 4 samples								
1	0.05	90	250	7500	11300	0.15	0.152	
2	0.05	90	250	6300	9900	0.167	0.156	
3	0.05	90	250	7400	10210	0.144	0.152	New Bolts used
4	0.05	90	250	7050	11150	0.136	0.154	
Average:				7062.5	10640	0.149	0.154	
No Aluminum Gasket used.								
1	0.05	90	250	5005	13600	N/A	N/A	No Aluminum Used
2	0.05	90	250	5010	12950	N/A	N/A	No Aluminum Used
3	0.05	90	250	7300	12440	N/A	N/A	No Aluminum Used
4	0.05	90	250	5200	12810	N/A	N/A	No Aluminum Used
Average:				5628.75	12950			
Steel and Aluminum Spacers Used:								
1	0.05	90	250	7050	8000	0.146	0.151	Al Spacers
2	0.05	90	250	5800	6810	0.143	0.157	Steel Spacers
3	0.05	90	250	5700	7005	0.158	0.153	Steel Spacers
4	0.05	90	250	5210	6100	—	—	Used Al Spacers
Average:				5940	6978.75	0.149	0.154	

OBSERVATIONS:

Based on the best representative sample from each different clamping configuration.

Aluminum gasket 250 ft*lbf with 90° weave. (Test #12)

Kevlar:	Failure along aluminum gasket location.
	Failures due to fraying and slip from around bolt holes.
Mylar:	Clearly indented along aluminum gasket. No holes or tears.
Data Curve:	Smooth with only 2 slips before maximum load reached.

Aluminum gasket 250 ft*lbf with 45° weave. (Tests #19 and #20)

Kevlar:	No failure by bolts or aluminum clamp.
	All failure in center region 3.75 inches wide.
Mylar:	Some indentation along gasket. One tear at frayed corner.
Data Curve:	Apparent yield point exists present.
	Very smooth line without slips or failures until maximum load reached.
	The yield could not be calculated because the load takes a hyperbolic shape for which the cross sectional area is indeterminate.

No aluminum gasket 250 ft*lbf 90° weave. (test #21)

Kevlar:	Failure outside clamped regions.
	Failure areas lined up between bolt locations.
	Fraying along edges very evident.
Mylar:	Fused slightly to kevlar. Easily removed with very little damage.
	No indentations except slight cloth weave pattern.
Data Curve:	Multiple slips and failures before maximum load reached.

Spacers with aluminum gasket at 250 ft*lbf 90° weave. (test #25)

No significant difference in performance of aluminum spacers and steel spacers.

Kevlar:	Severe failure along Al gasket. Bolt holes remain intact.
	Little fraying except along edges.
Mylar:	Both gasket and spacer indentations visible. No tearing, remained intact.
Spacers:	Some seemingly untouched, others severely indented or bent. Aluminum spacers sustained more damage.
Data Curve:	Smooth until several failures immediately before maximum load.

DISCUSSION OF DATA:

All tests had failures resulting from fraying along exposed edges. This would not happen if fabric pulled uniformly in all directions. Fraying would also be reduced with the use of epoxy as all previous windows were constructed. The actual window would be able to sustain higher loads than tensile samples.

45° weave tests formed hyperbolic shaped tension region resulting in higher fraying and indeterminable cross sectional area. Most 45° weave tests results are not helpful contributors to the data desired.

First eleven tests used to find minimal torque at which target loads of 13094 and 6845 lbf would be met or exceeded.

Widespread values of maximum loads indicate tests not completely valid. Experience and design theory should not be blatantly overridden by these results.

Data for the first slip and maximum load included to provide information on which to base safety factors. Fraying edges often the cause for first slip. At this value vacuum may be lost, in the window application, but no severe endangering failure would occur.

Tests in which spacers were used suspect because of the difficulty in assembly of test samples. The difficulty and failure to assemble good samples clearly shown by damage to the mylar and spacers. Better assembly needed than could be done with this test apparatus.

NOTE: Scales change from test to test on graphs so read test curves carefully.
NOTE: The machine could test to a maximum load of 13000 lbf so tests at higher torques were not done.

CONCLUSIONS:

Tears in mylar pieces was primarily due to slips after the maximum load failure, not from the assembly process. The damage incurred because test was taken to failure. The mylar did become permanently indented.

At 250 ft*lbf a total bolt load of 54395 lbf is exerted on the fixture. The resulting average X dimension on the aluminum gasket of 0.149 yields a compressive force of 37032 psi. This compressive force is higher than mylar's yield and ultimate strengths but failure did not occur since mylar is extremely elastic. This force is below the strength of kevlar so no damage to the cloth was induced by the assembly.

Significantly less damage to the mylar occurred on the tests without the aluminum gasket.

250 ft*lbf torque was necessary with the aluminum gasket to obtain a first slip above the desired 6845 lbf. The first slip for samples without a gasket occurred at a much lower value than either with the gasket or the desired load. Therefore the aluminum gasket significantly aided a secure hold.

The aluminum gasket was not deformed to flush with the clamping fixture and did supply the primary compressive force. This is clearly shown by an average Y of 0.154 which is greater than the maximum 0.145 depth of the slot.

The highest maximum load at 250 ft*lbf torque was attained without the gasket. this would show that the gasket did contribute to failure at maximum loads.

Spacers yielded unacceptable results for both first slip and maximum load. To align all spacers correctly is very difficult and was never done successfully in these tests.

Increased torques would improve the performance of all fixtures and would be reasonable based on past window construction and performance.

45 psi ANSYS: $T_x = 296280$ lbs

T_x PER LINEAR INCH OF THE CIRCUMFERENCE

$$\bar{T}_{x_i} = \frac{296280}{\pi(71)} = 1328.2 \ \underline{\text{lbs}}$$

FOR 9.858 WIDE FIXTURE —

$$\bar{T}_{x_9} = \underline{13,094} \quad [\text{lbs}]$$

14.7 psi ANSYS:

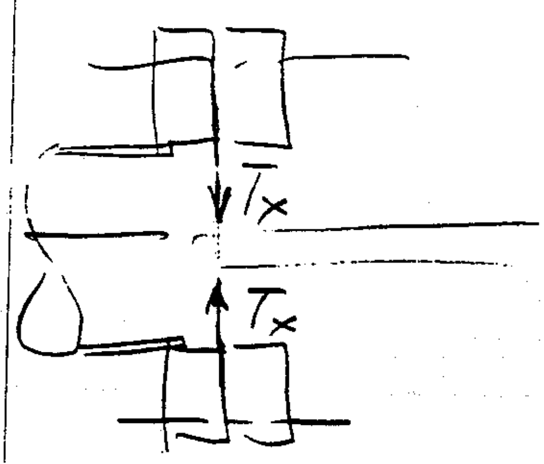
$T_x = 154880$ lbs

T_x PER LINEAR INCH OF THE CIRCUMFEREN

$$T_{x_i} = \frac{154880}{\pi(71)} = 694.36$$

FOR 9.858 WIDE FIXTURE

$$T_{x_9} = \underline{6845} \quad [\text{lbs}]$$



KEVLAR

K•E 10 X 10 TO THE INCH • 7 X 10 INCHES
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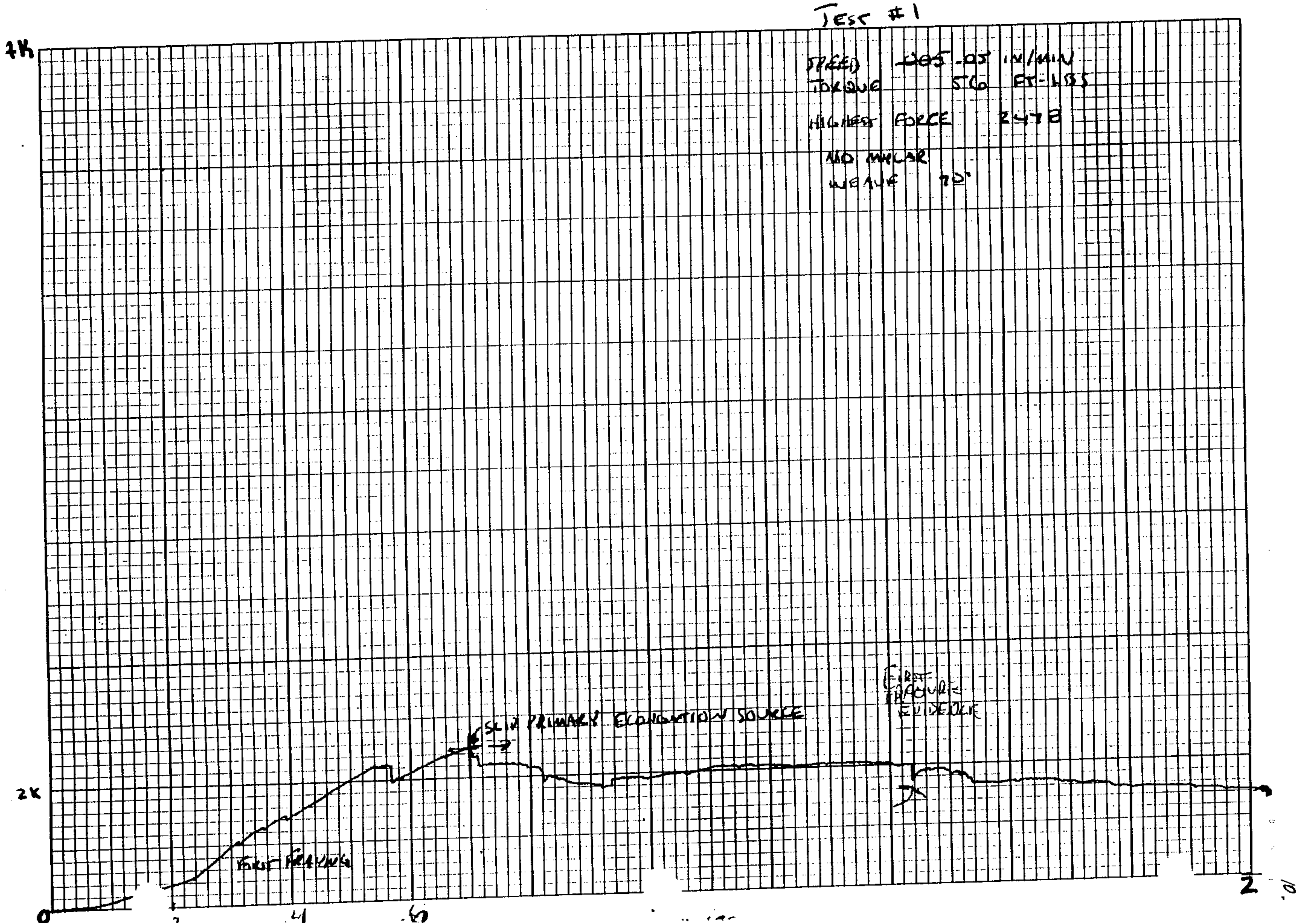

K•E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

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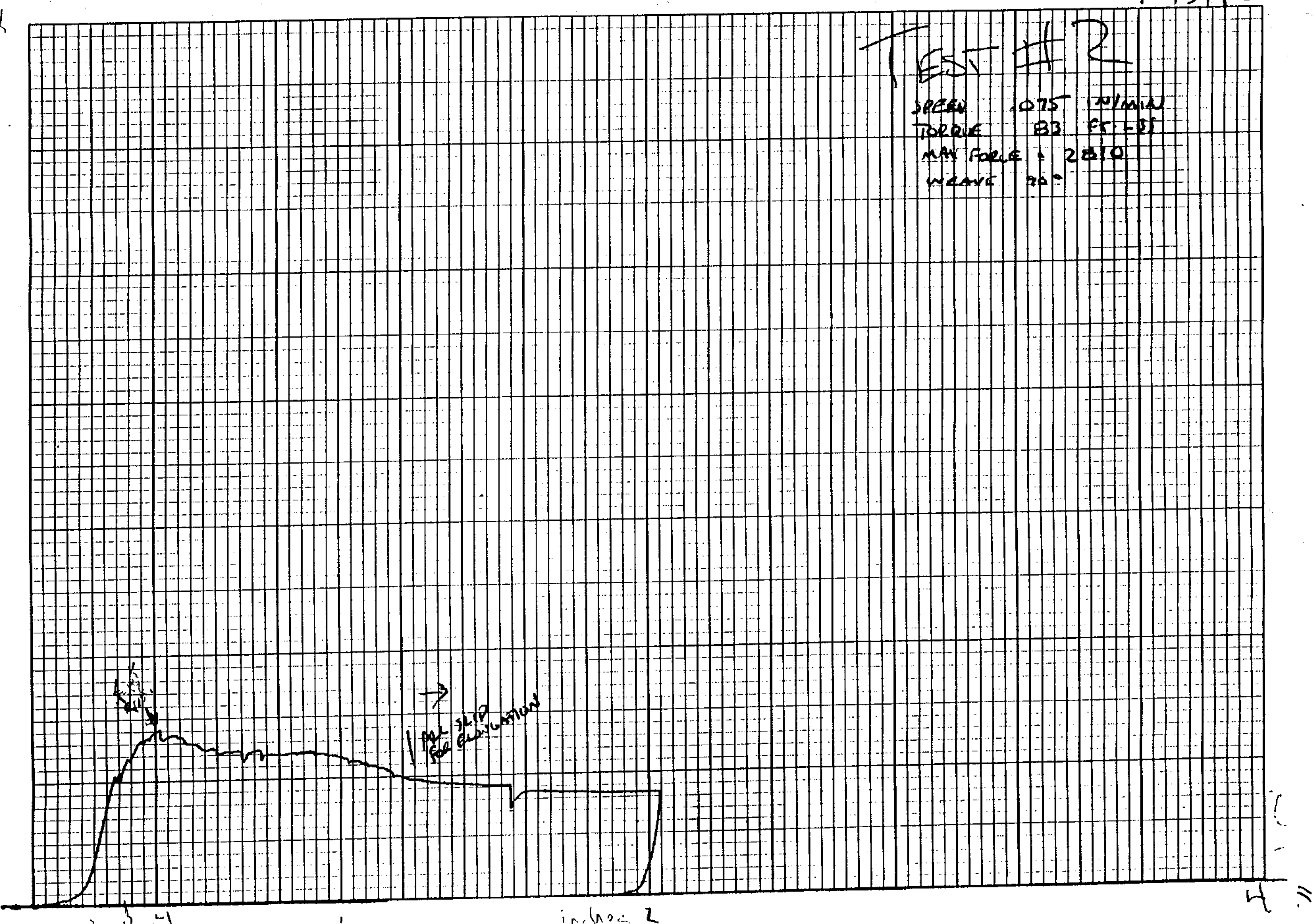

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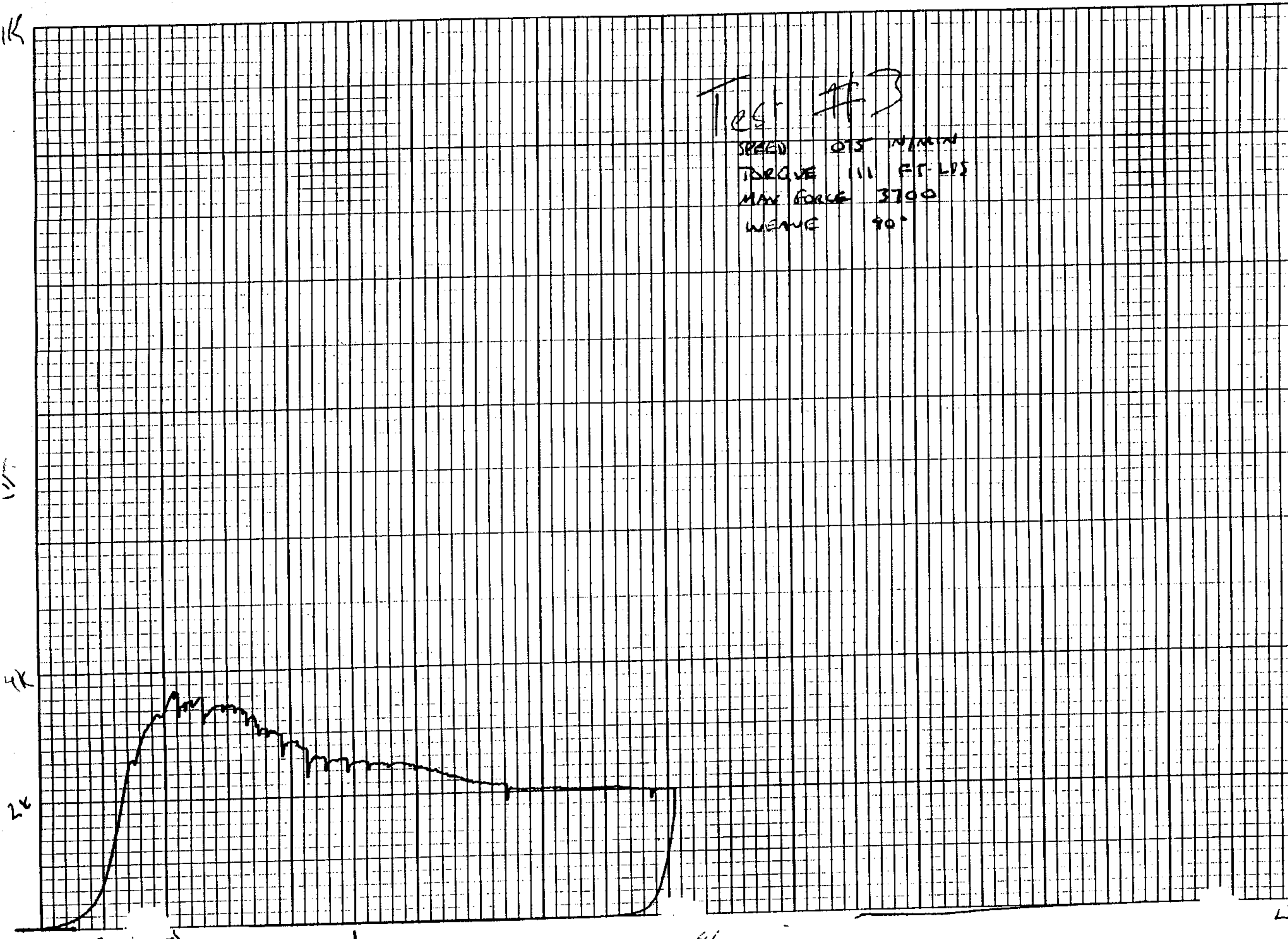
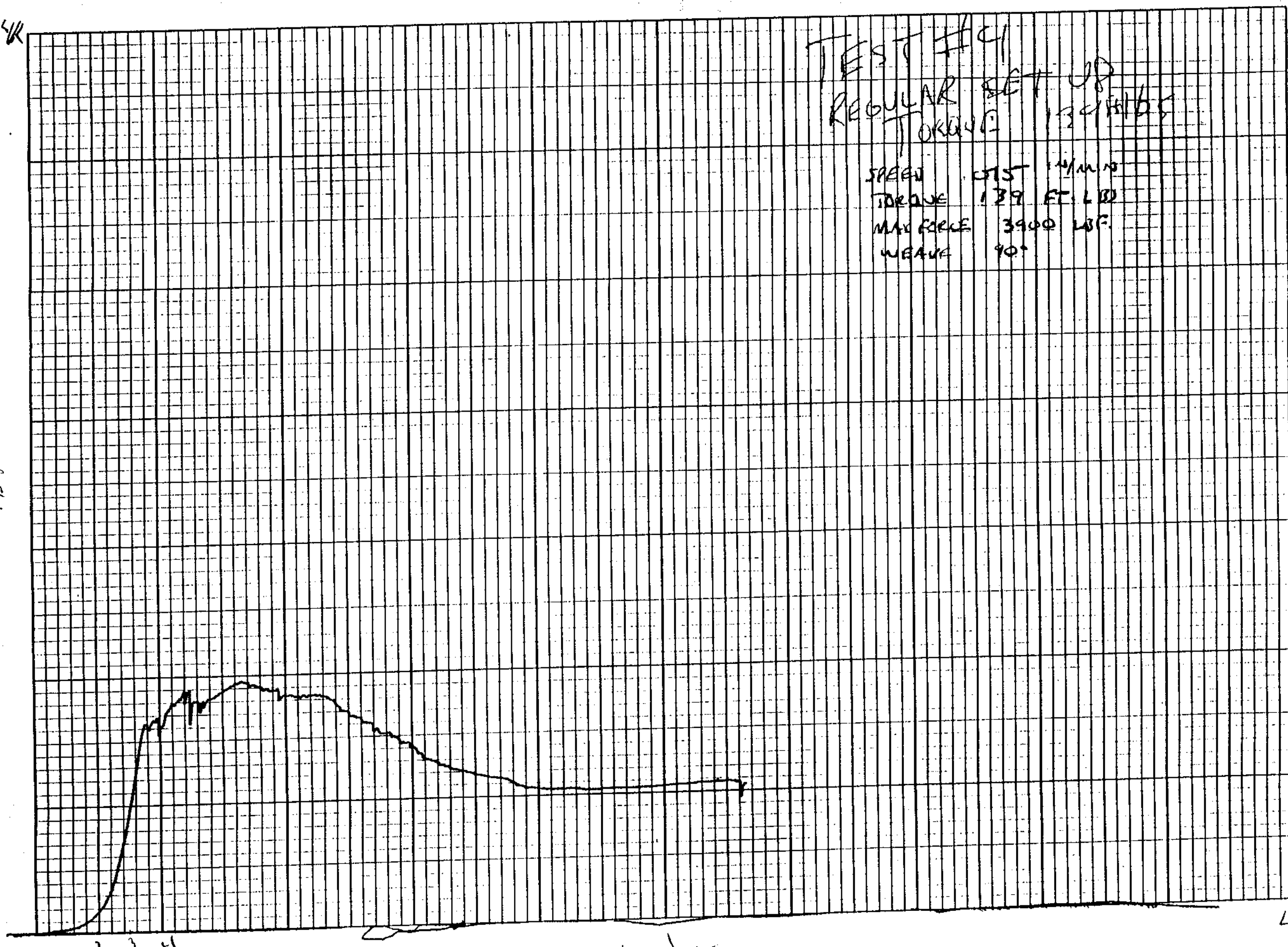

Test #3
SPEED .075 IN/MIN
TORQUE 111 FT-LBS
MAX FORCE 3700
WEAVE 90°
4K
2K

K•E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0780



4 13.

K•E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

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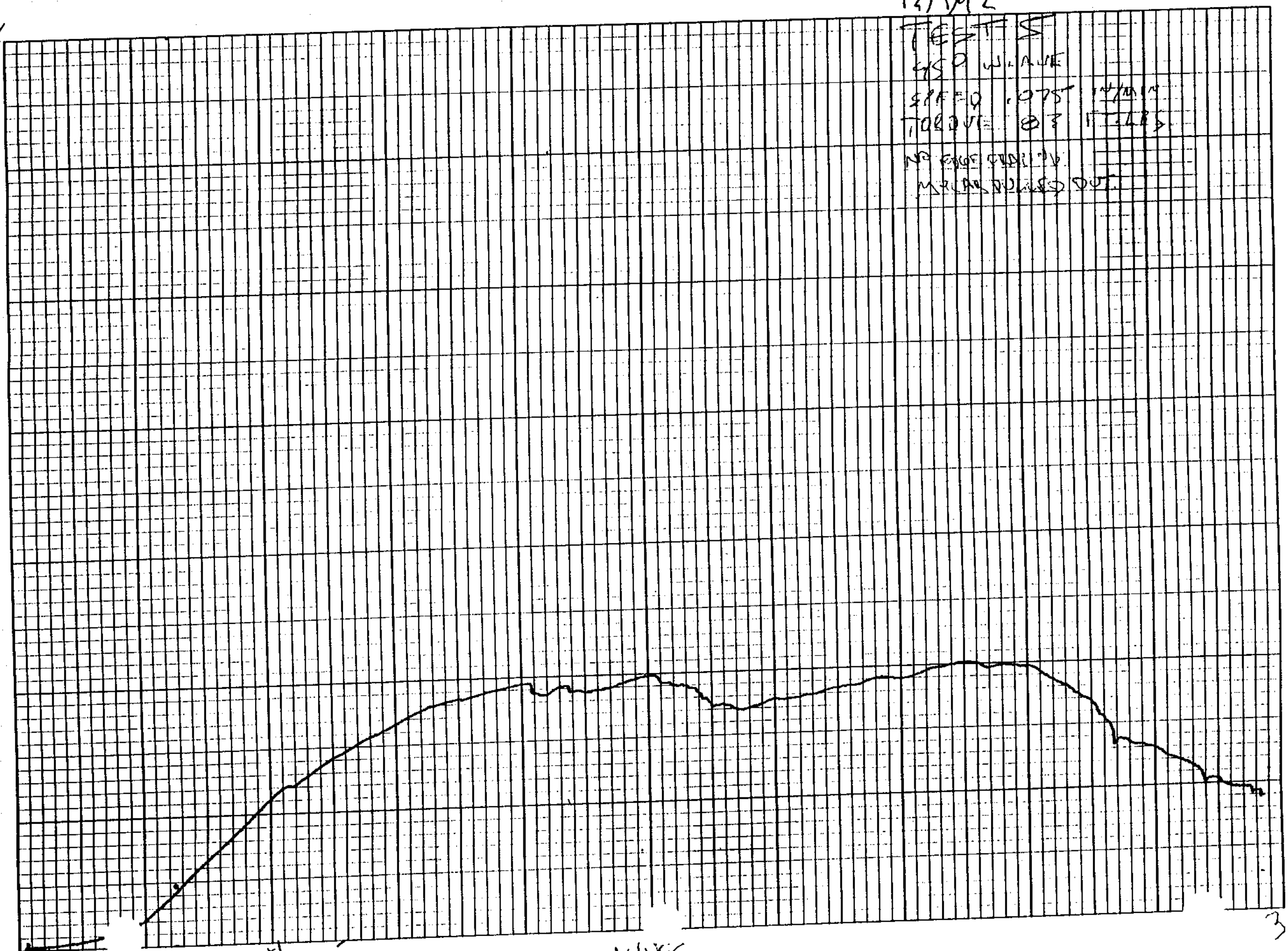

K•E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

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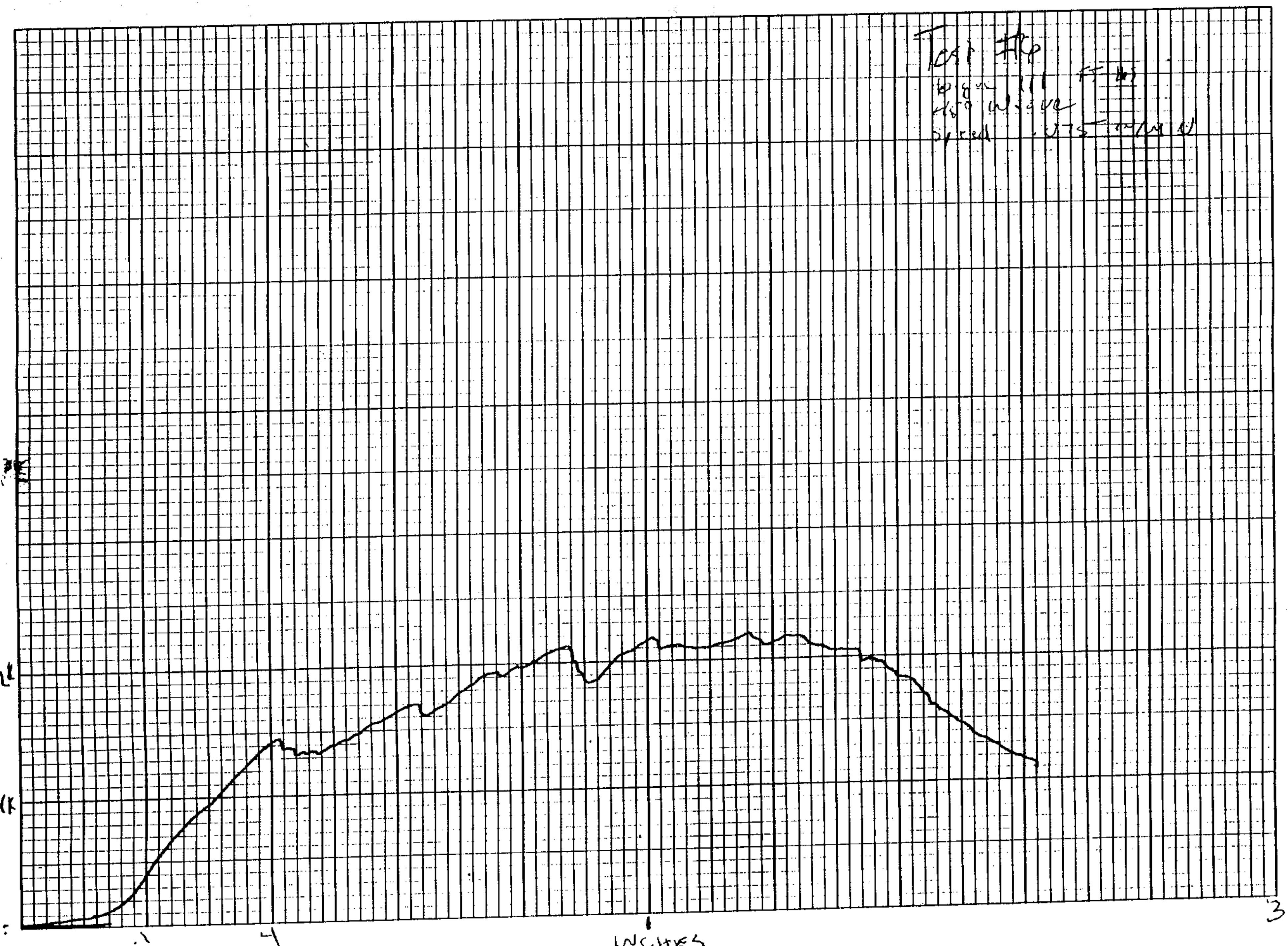
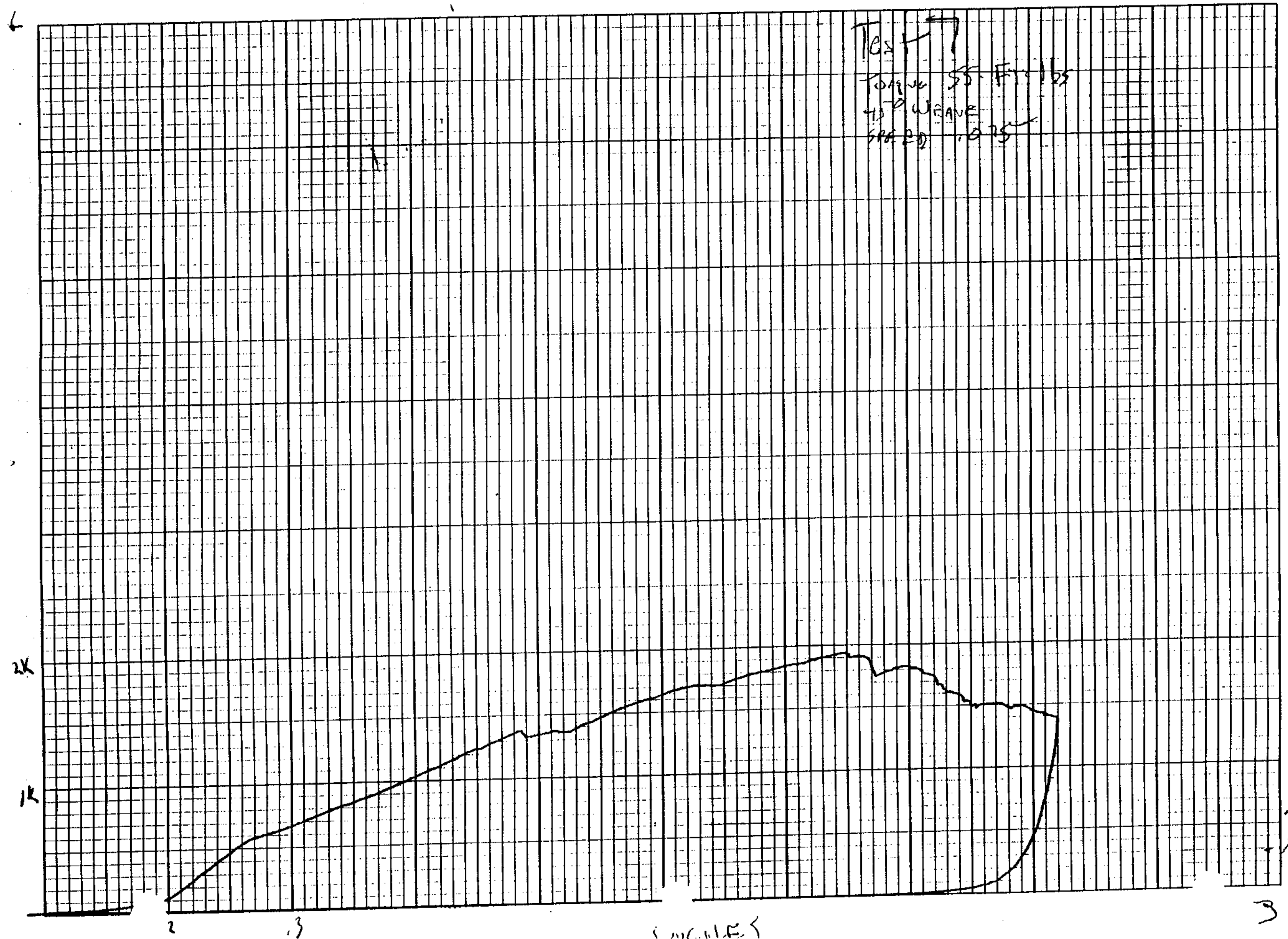
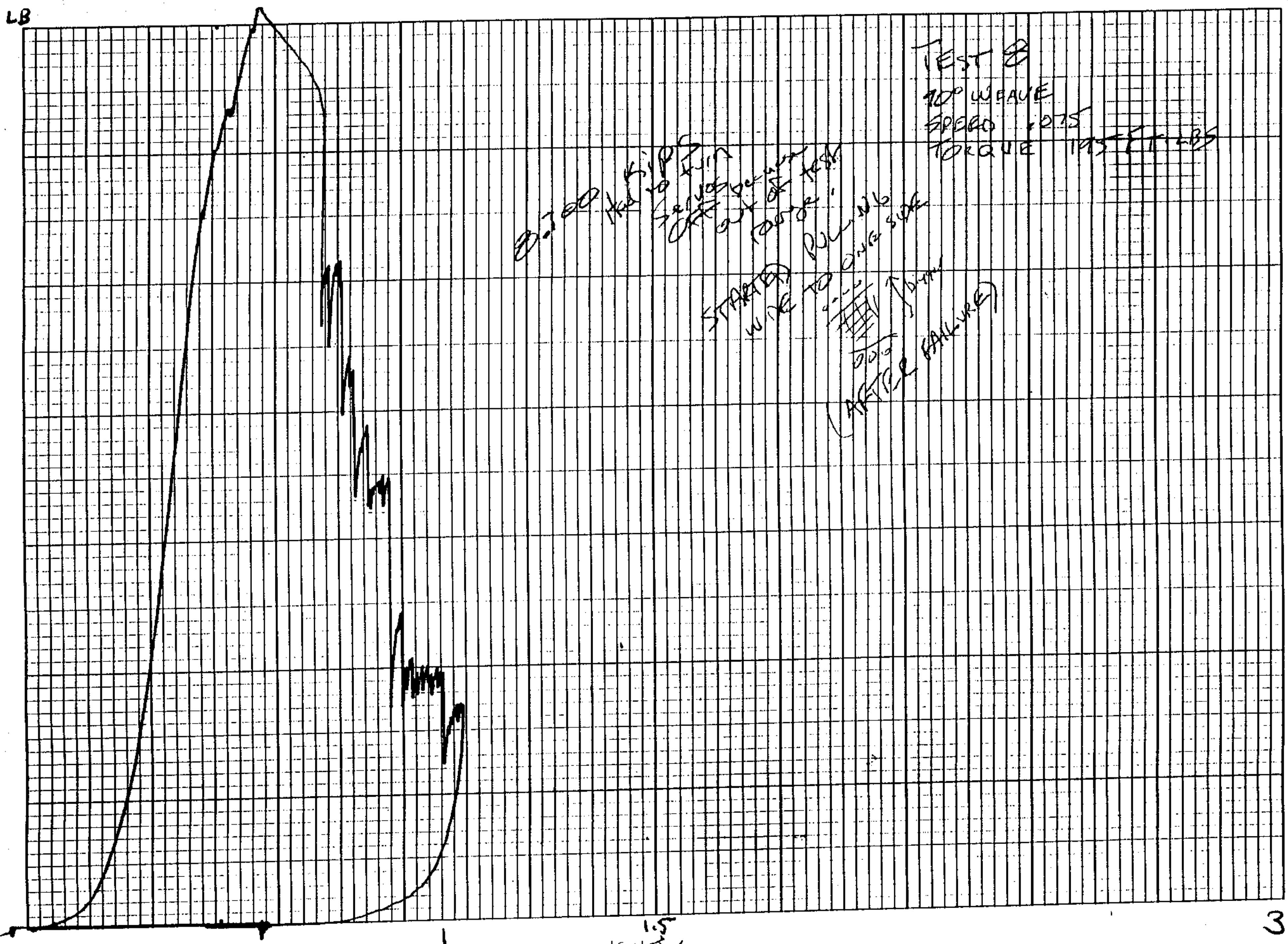



Test 7
Torque 55 Ft lbs
45° Weave
Speed .075
2K
1K
.2
.3

K•E 10 X 10 TO THE INCH • 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0780



17.

K•E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

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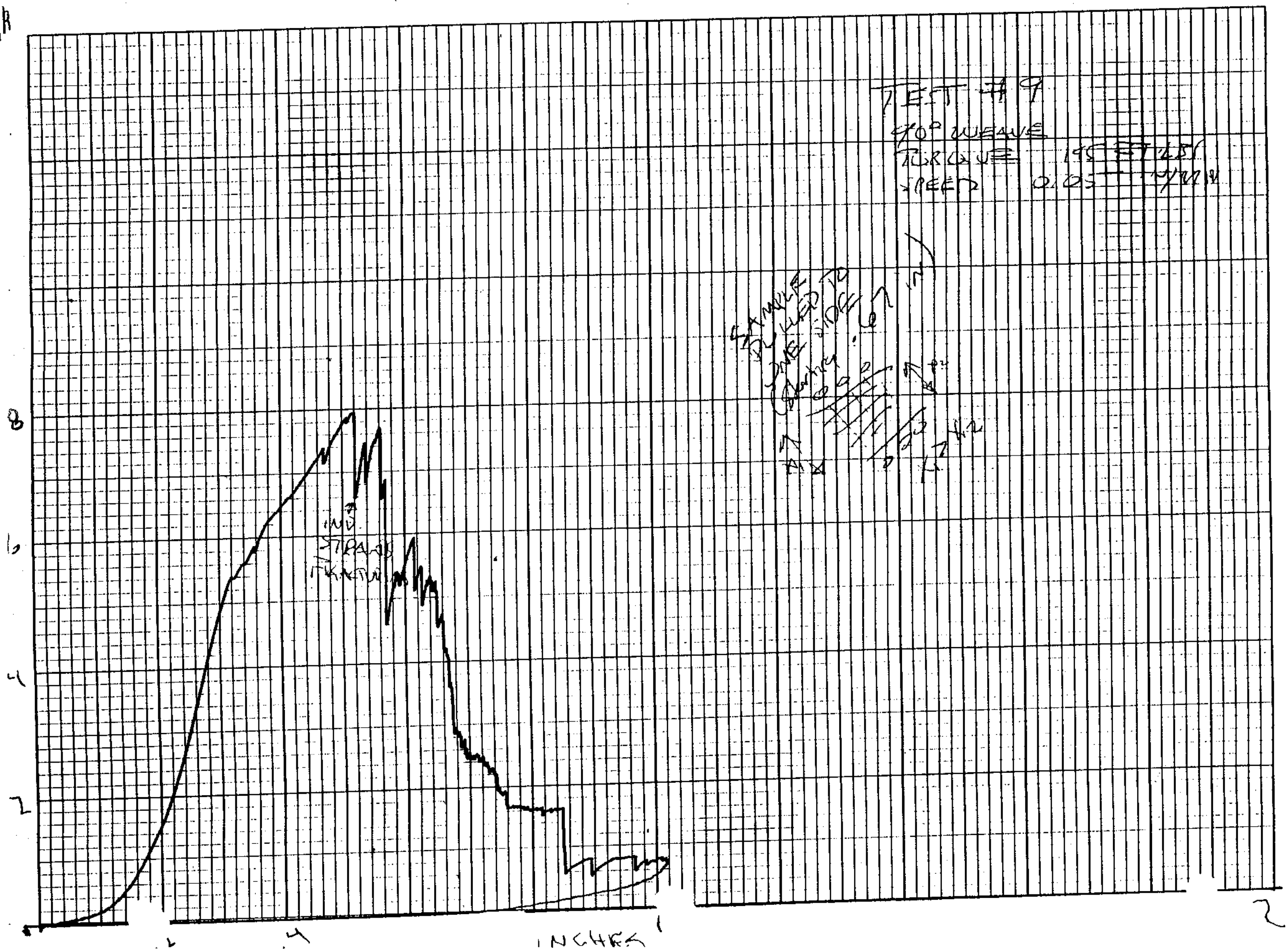

K&E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

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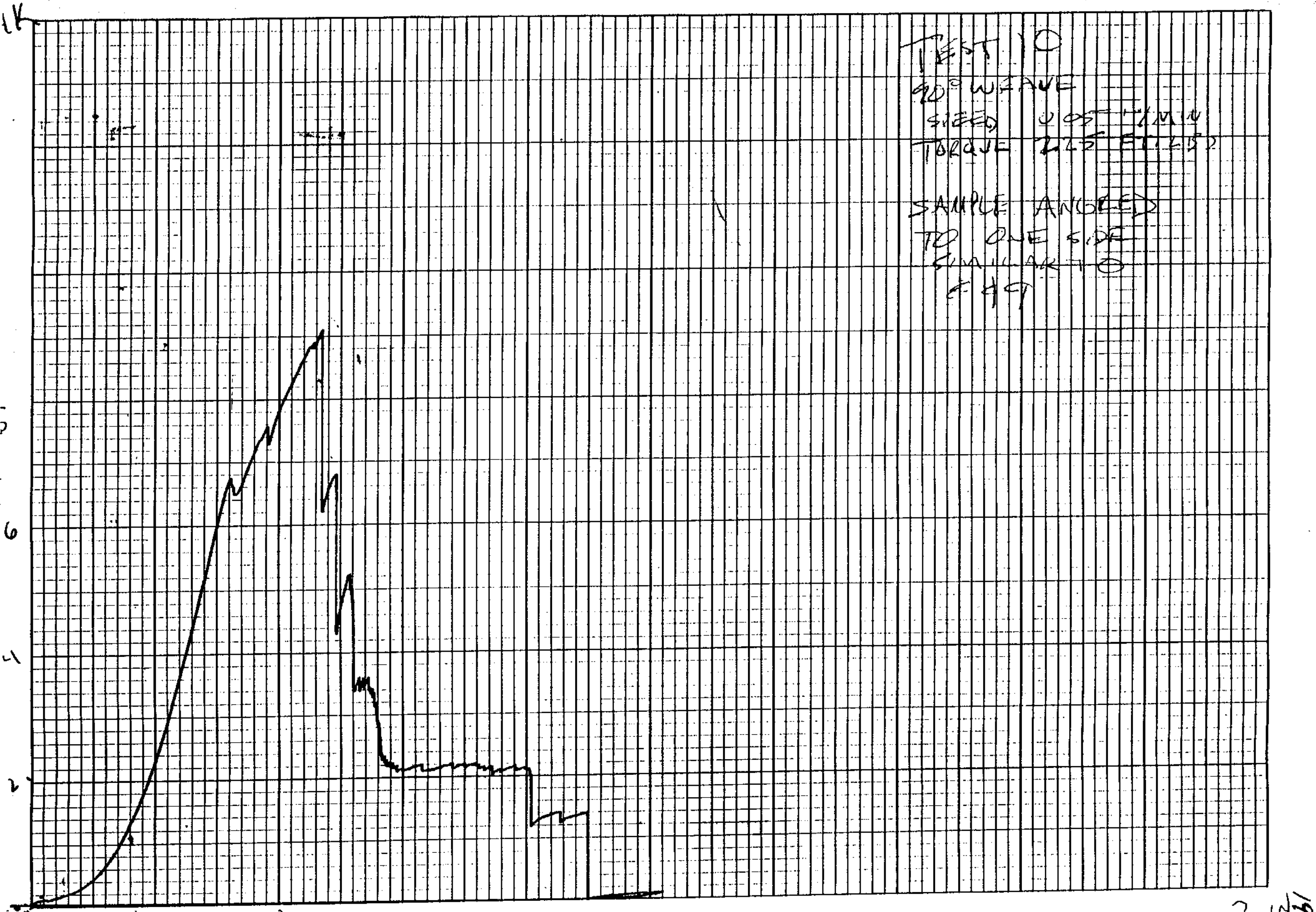

K•E 10 X 10 TO THE INCH • 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A.

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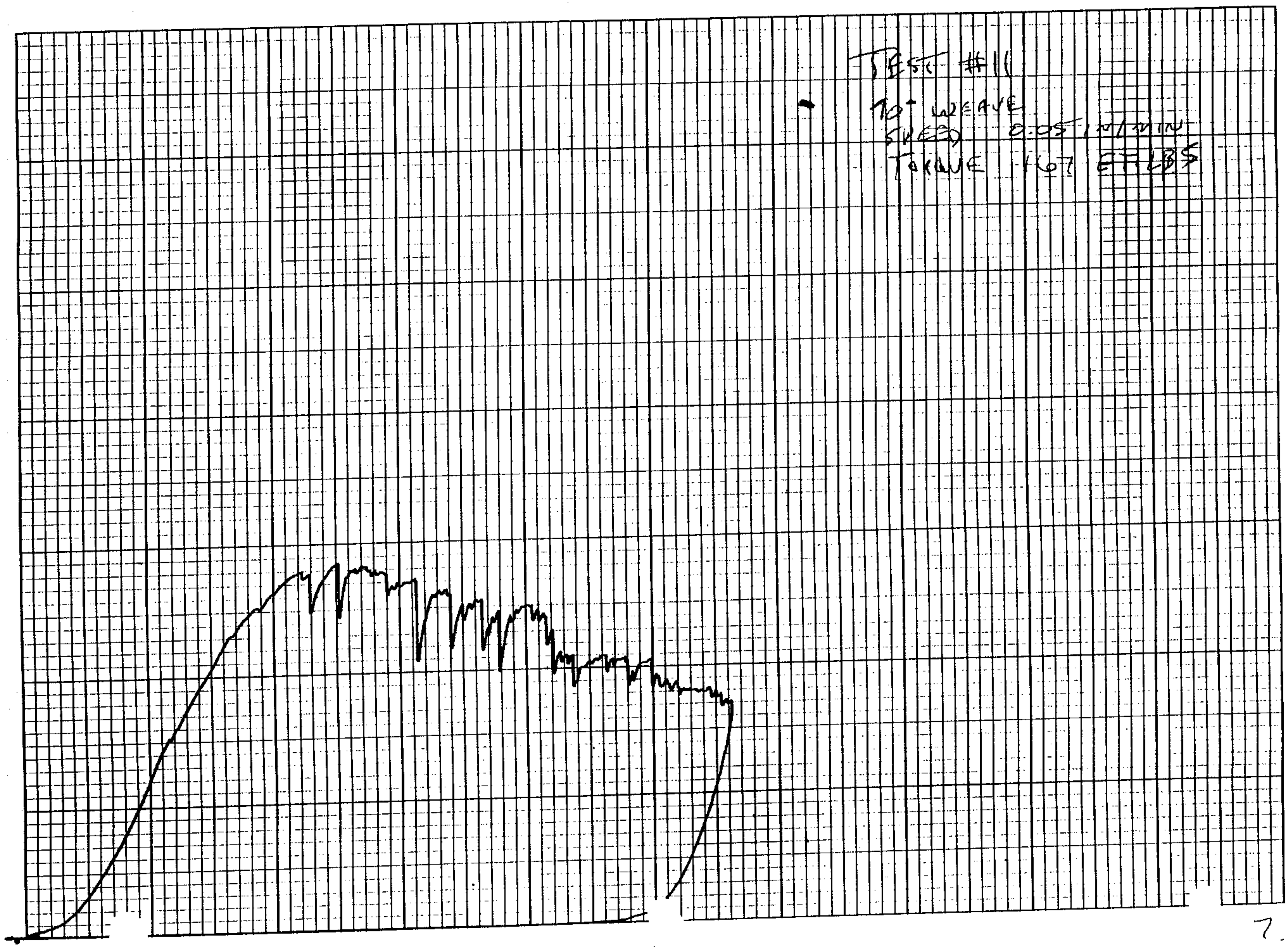

K•E 10 X 10 TO THE INCH • 7 X 10 INCHES
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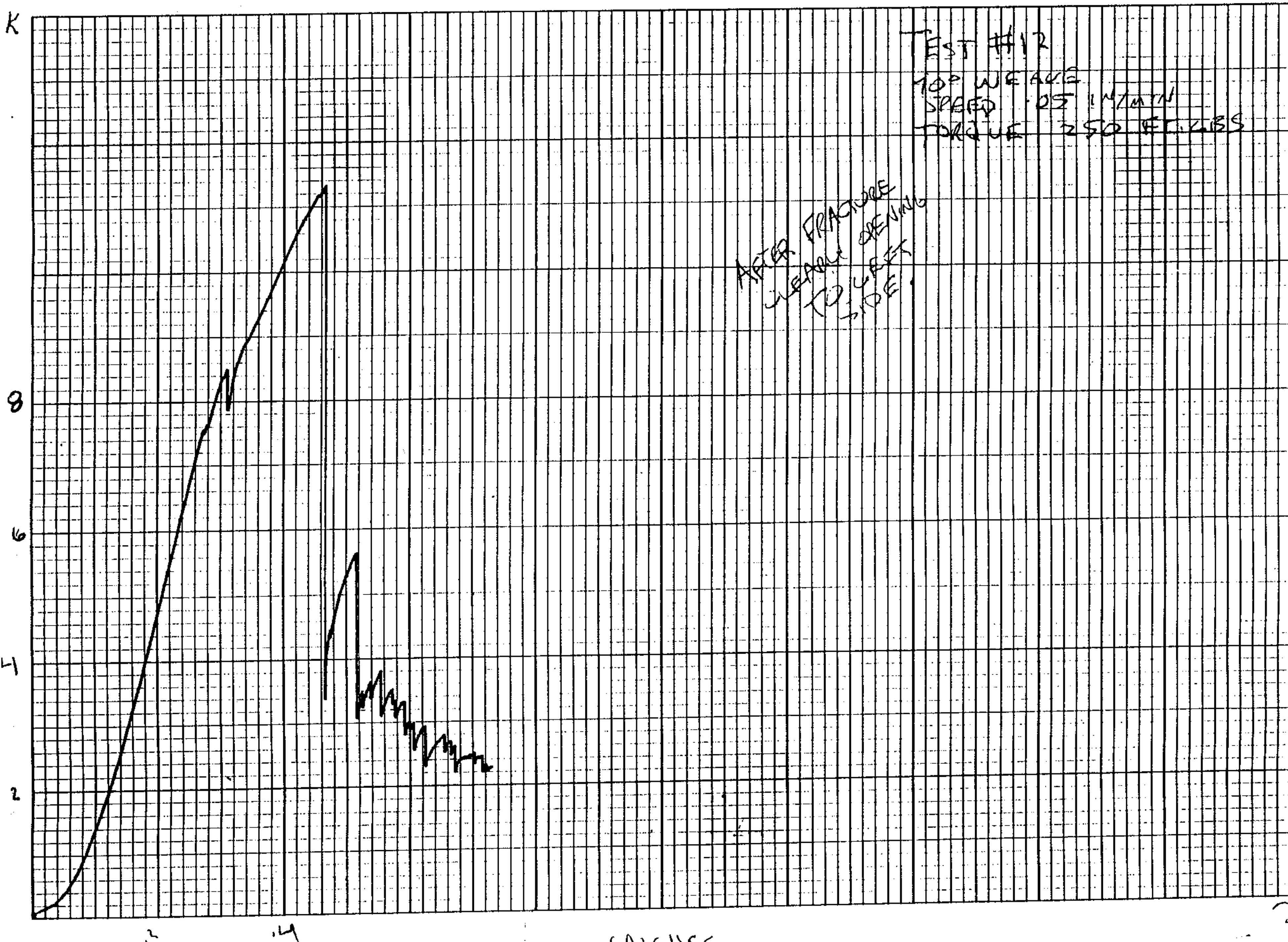

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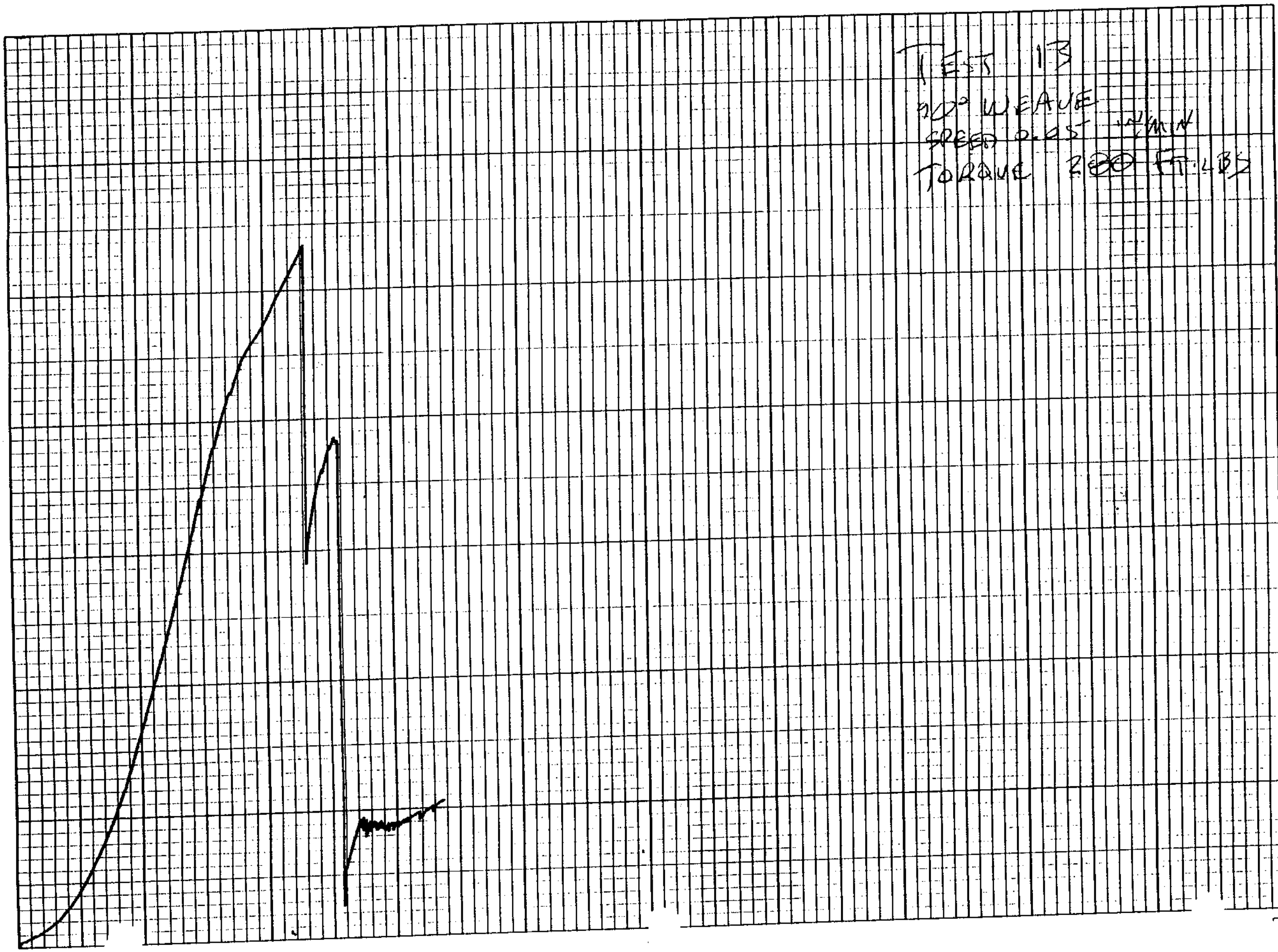
TEST 13
90° WEAVE
SPEED 0.05 in/MIN
TORQUE 200 FT-LBS

K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

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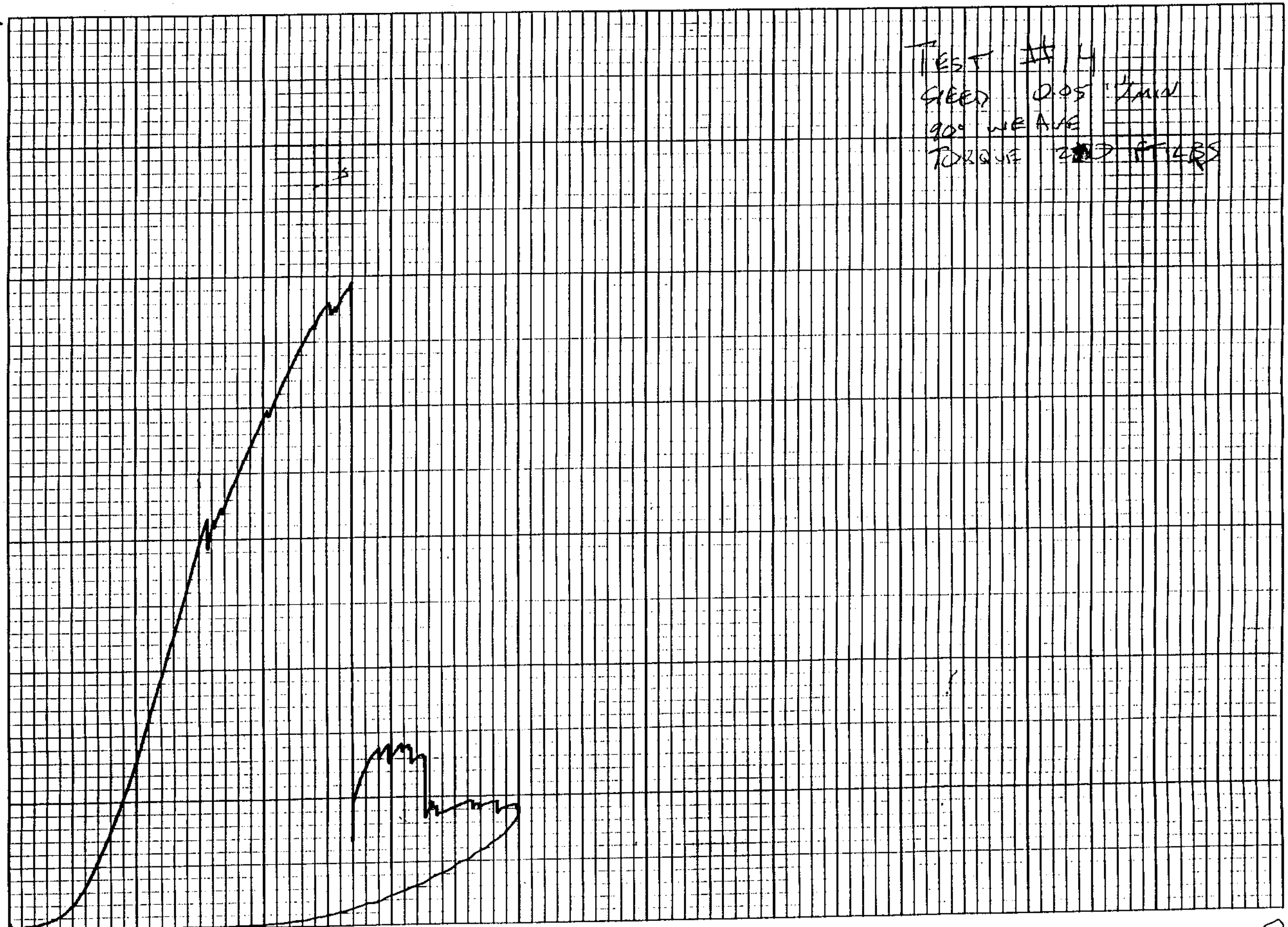
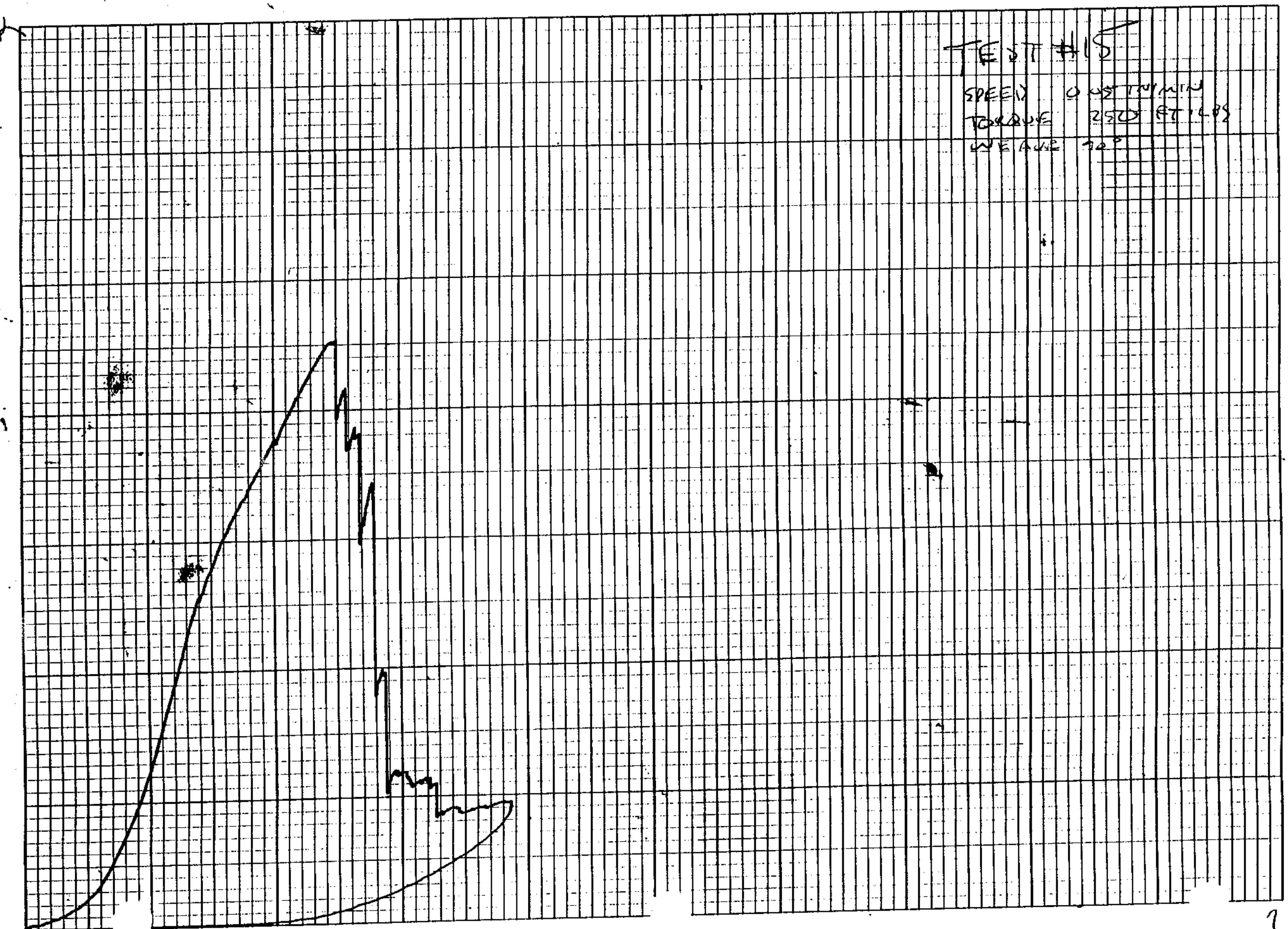
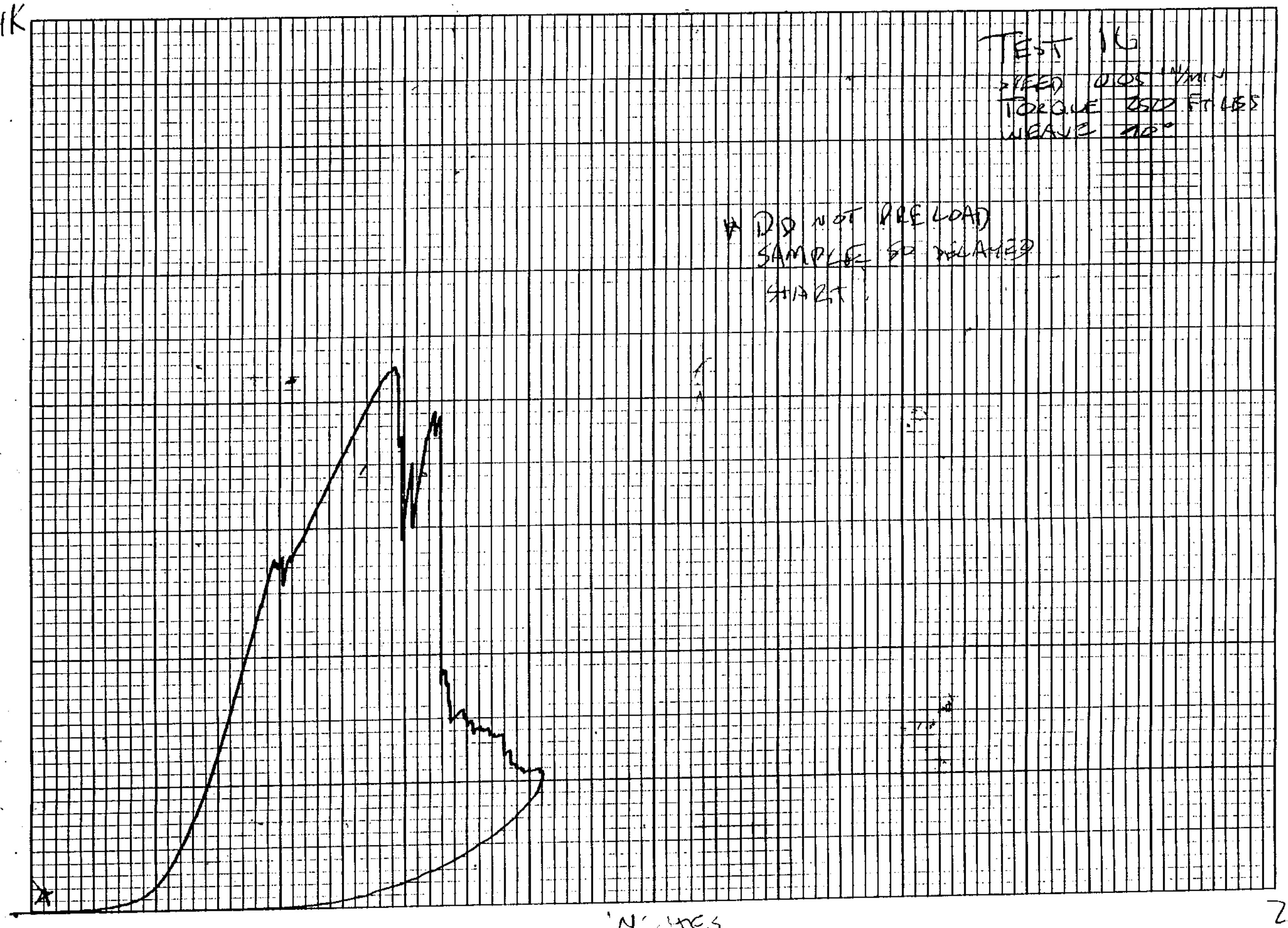



TEST #15
SPEED 0.05 IN/MIN
TORQUE 250 FT-LBS
WEAVE 90°

K•E 10 X 10 TO THE INCH • 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0780



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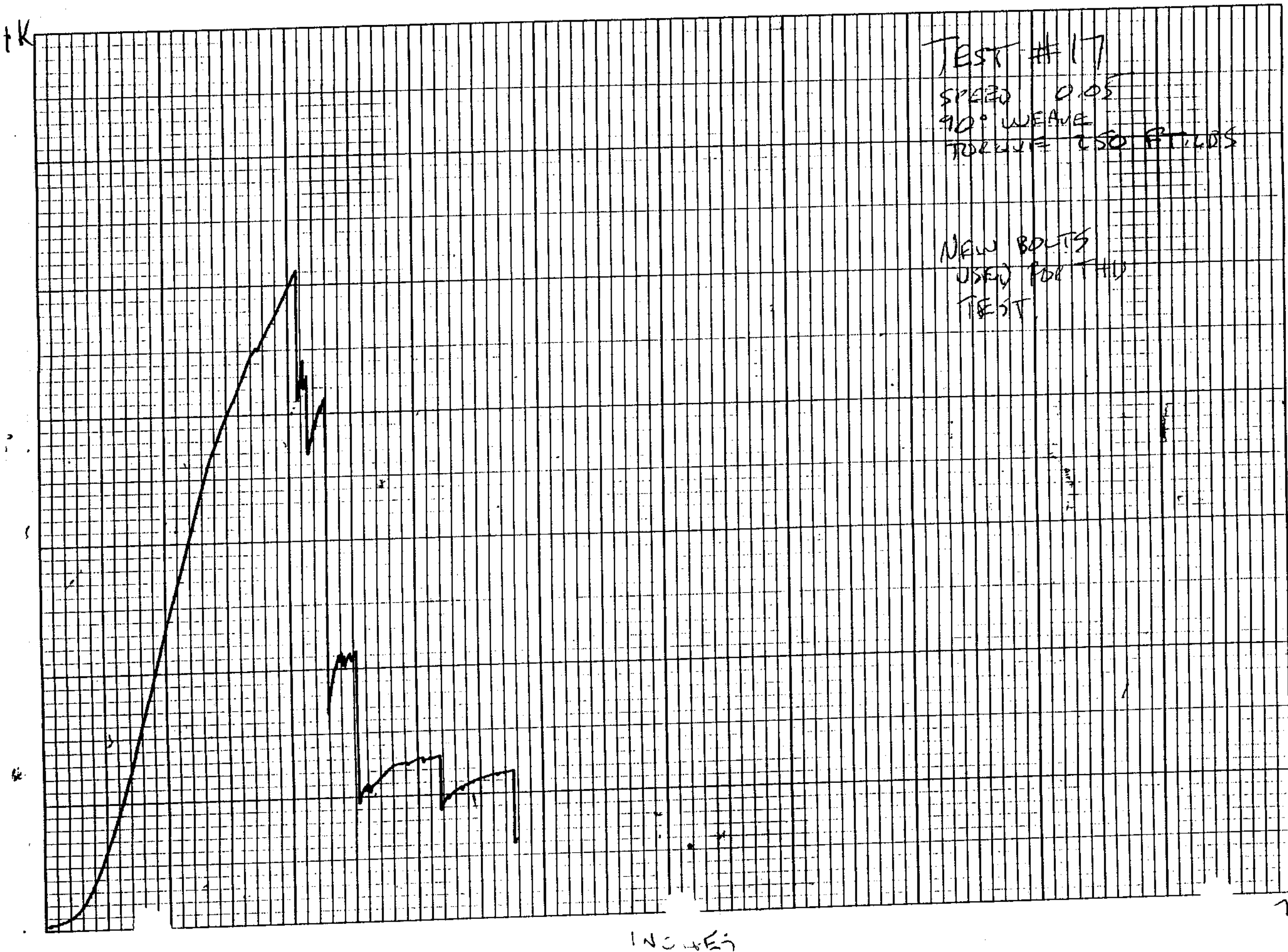
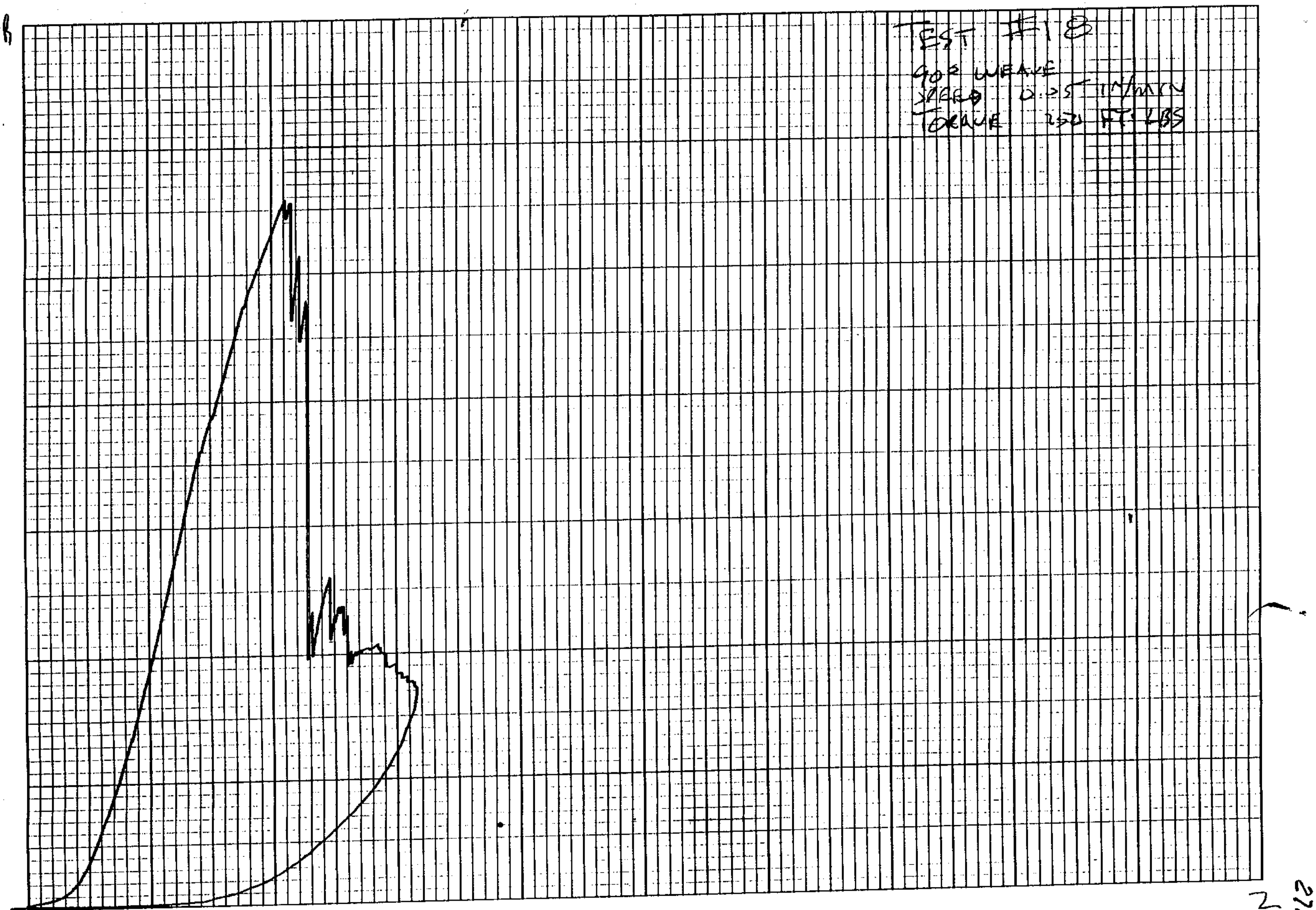

1K
TEST #17
SPEED 0.05
90° WEAVE
TORQUE 250 FT-LBS
NEW BOLTS
USED FOR THIS
TEST
2
INCHES

K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0780



27.

K•E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

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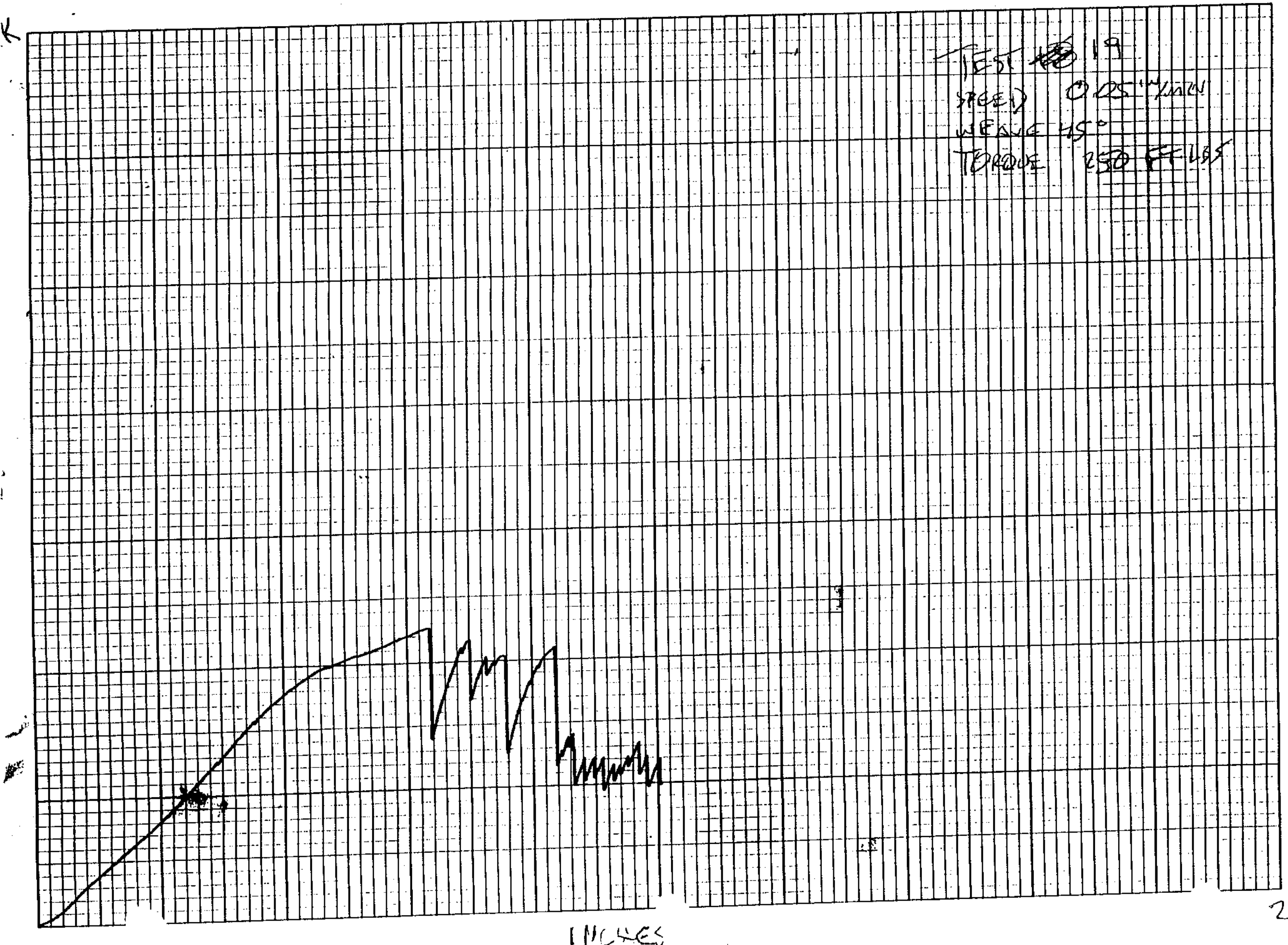

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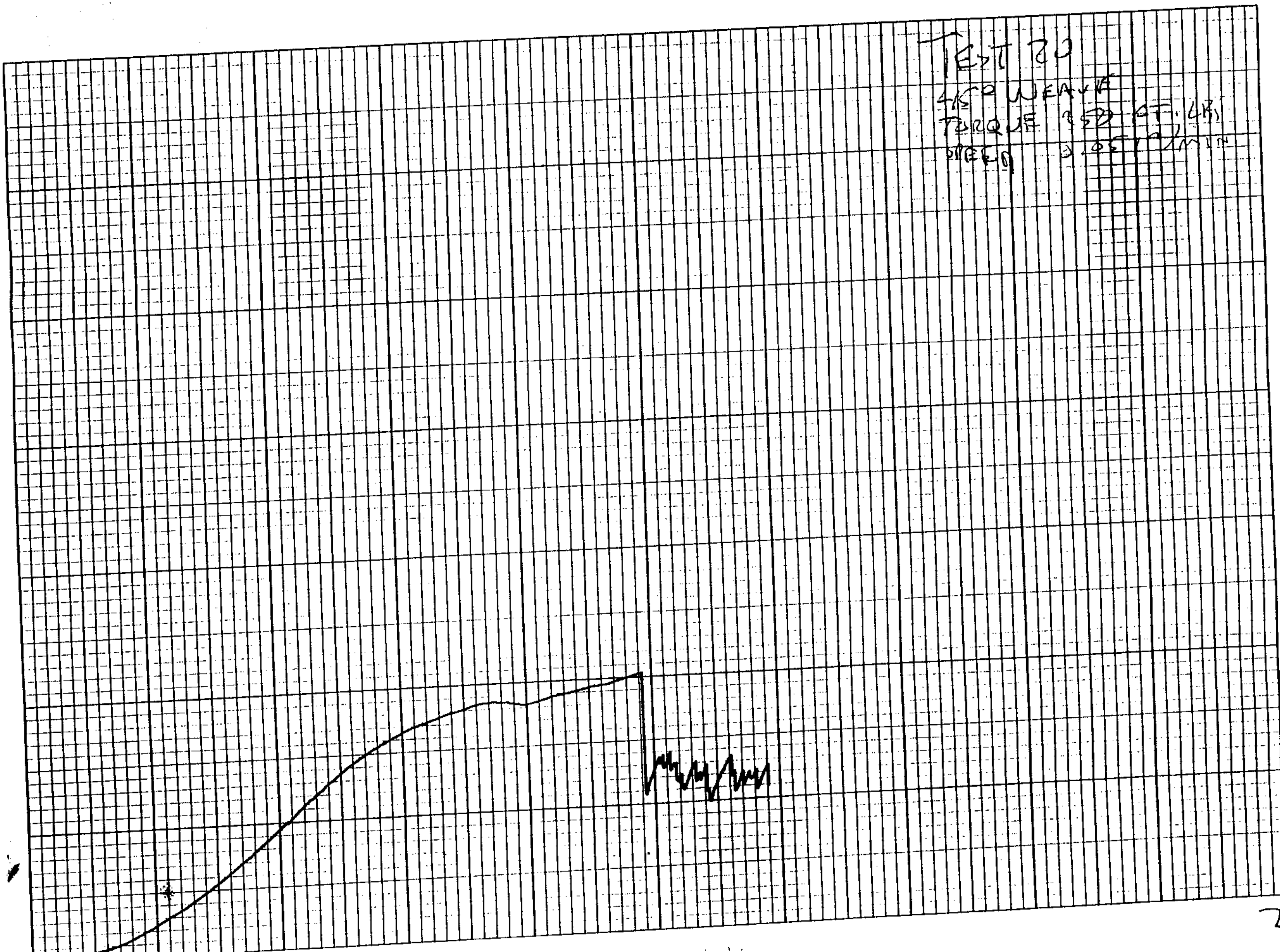
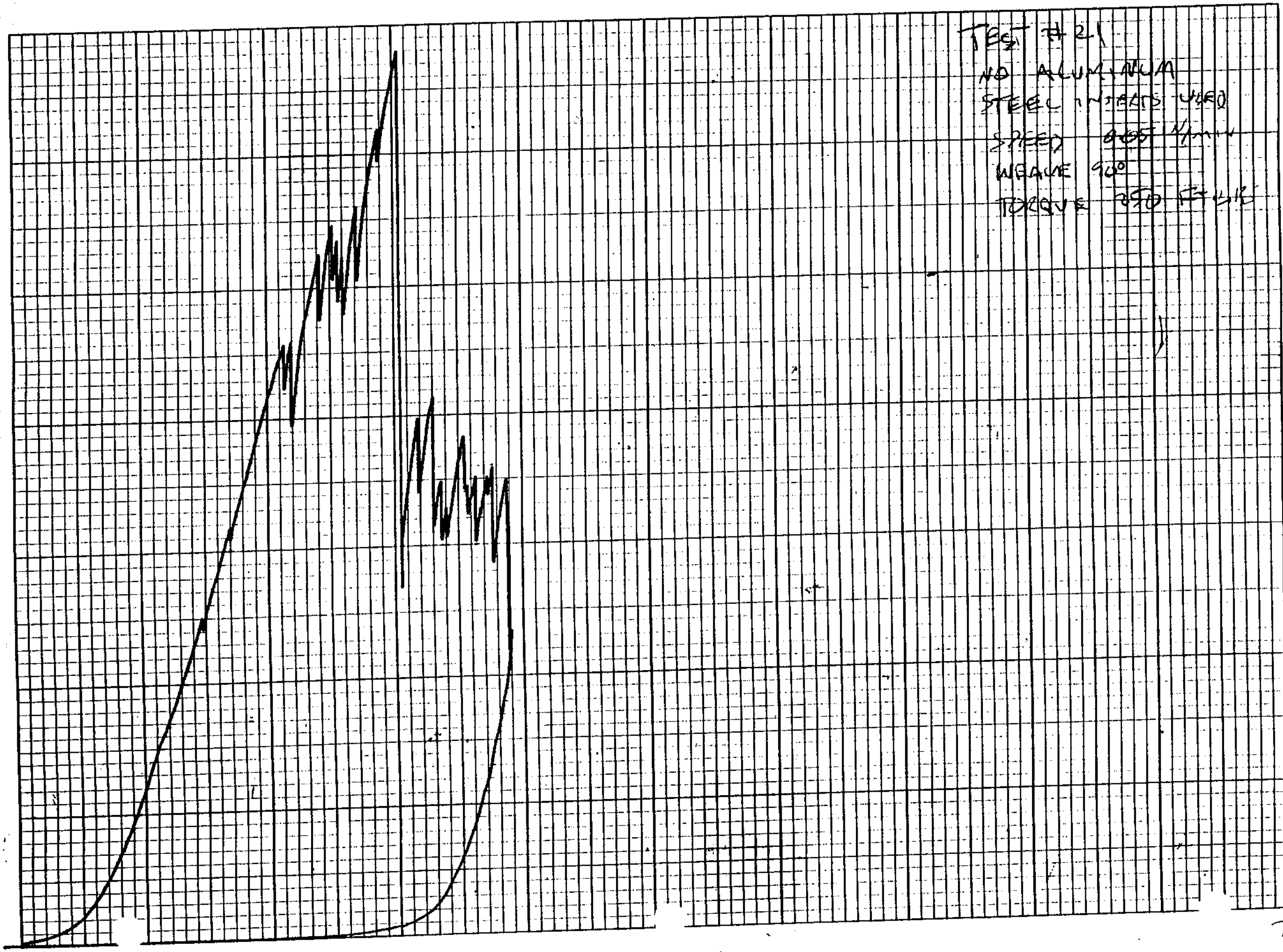

TEST 20
45° WEAVE
TORQUE 350 FT.-LBS
SPEED 0.05 IN/MIN

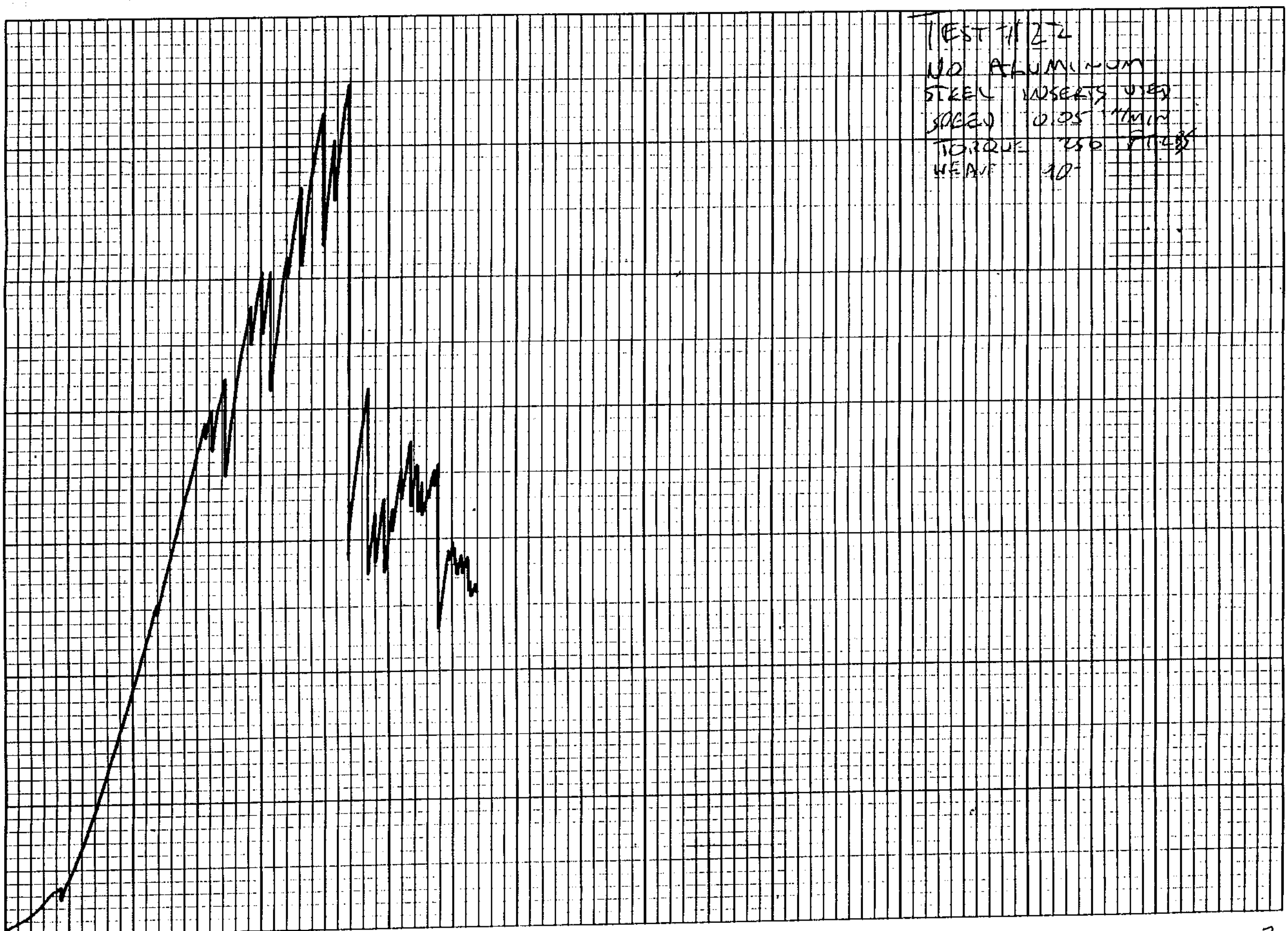
46 0780


TEST #21
NO ALUMINUM
STEEL INSTEAD USED
SPEED .005 "/MIN
WEAVE 90°
TORQUE 250 FT-LB

IN. .ES

K•E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0780



K•E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

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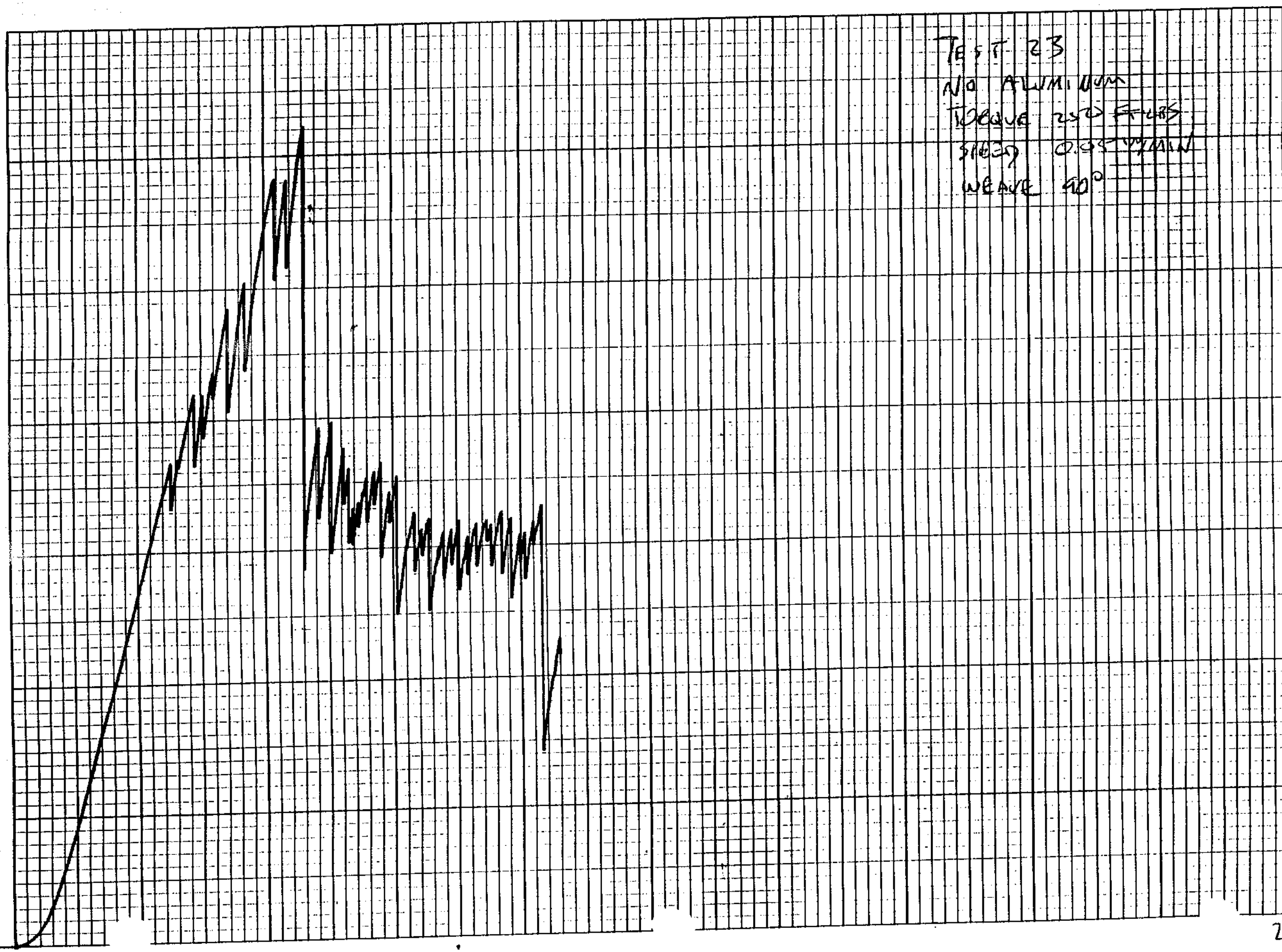
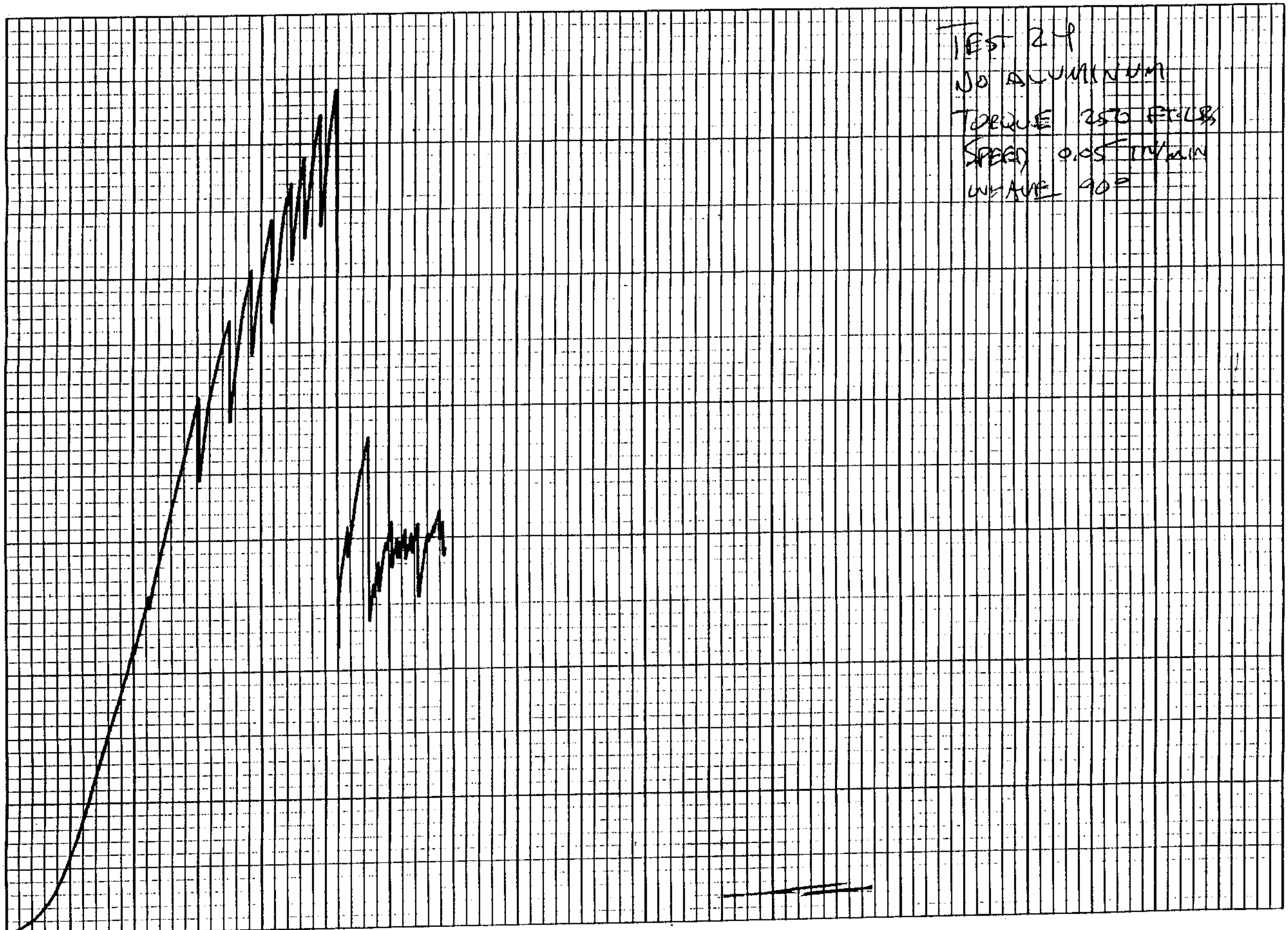
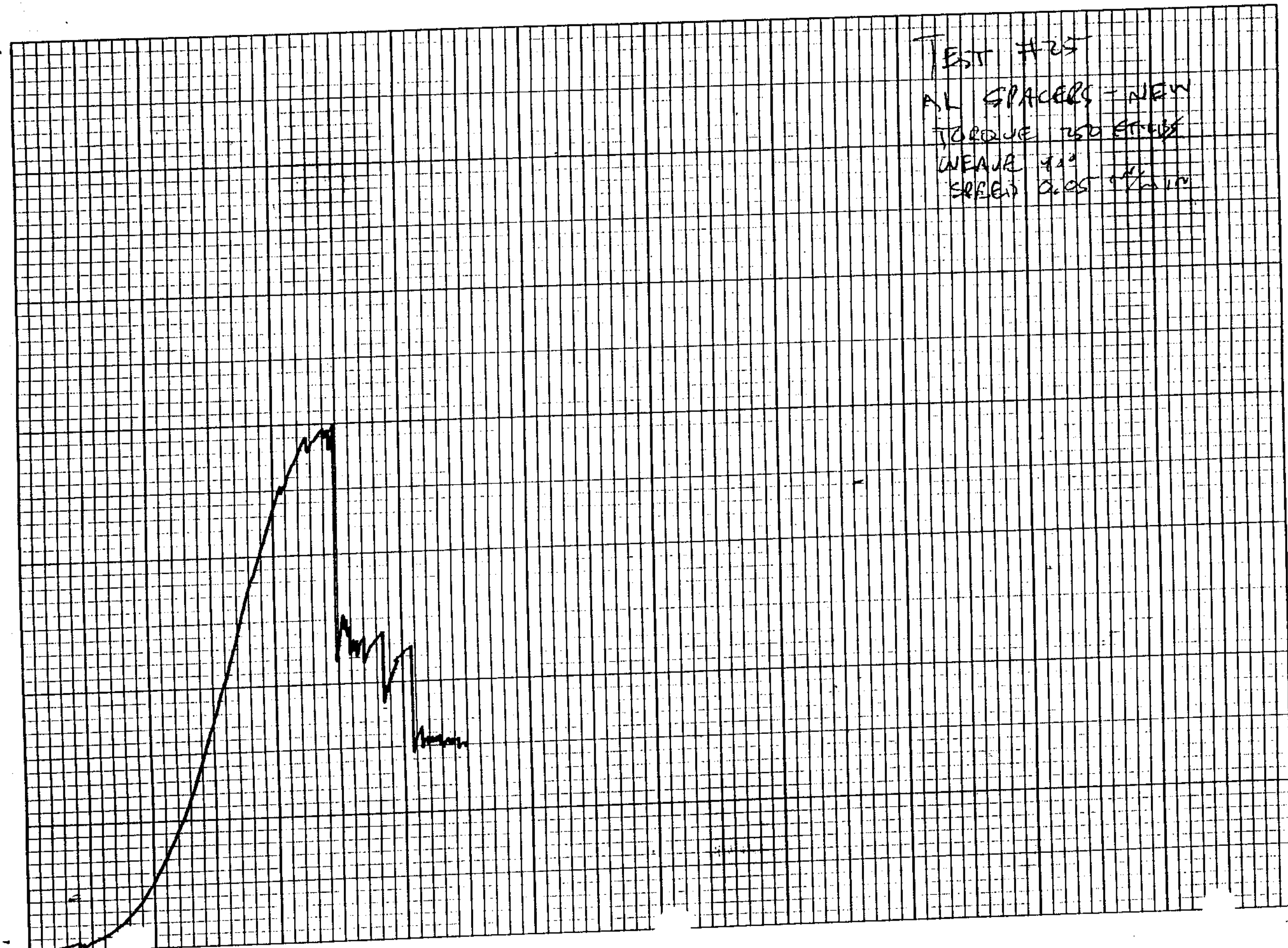
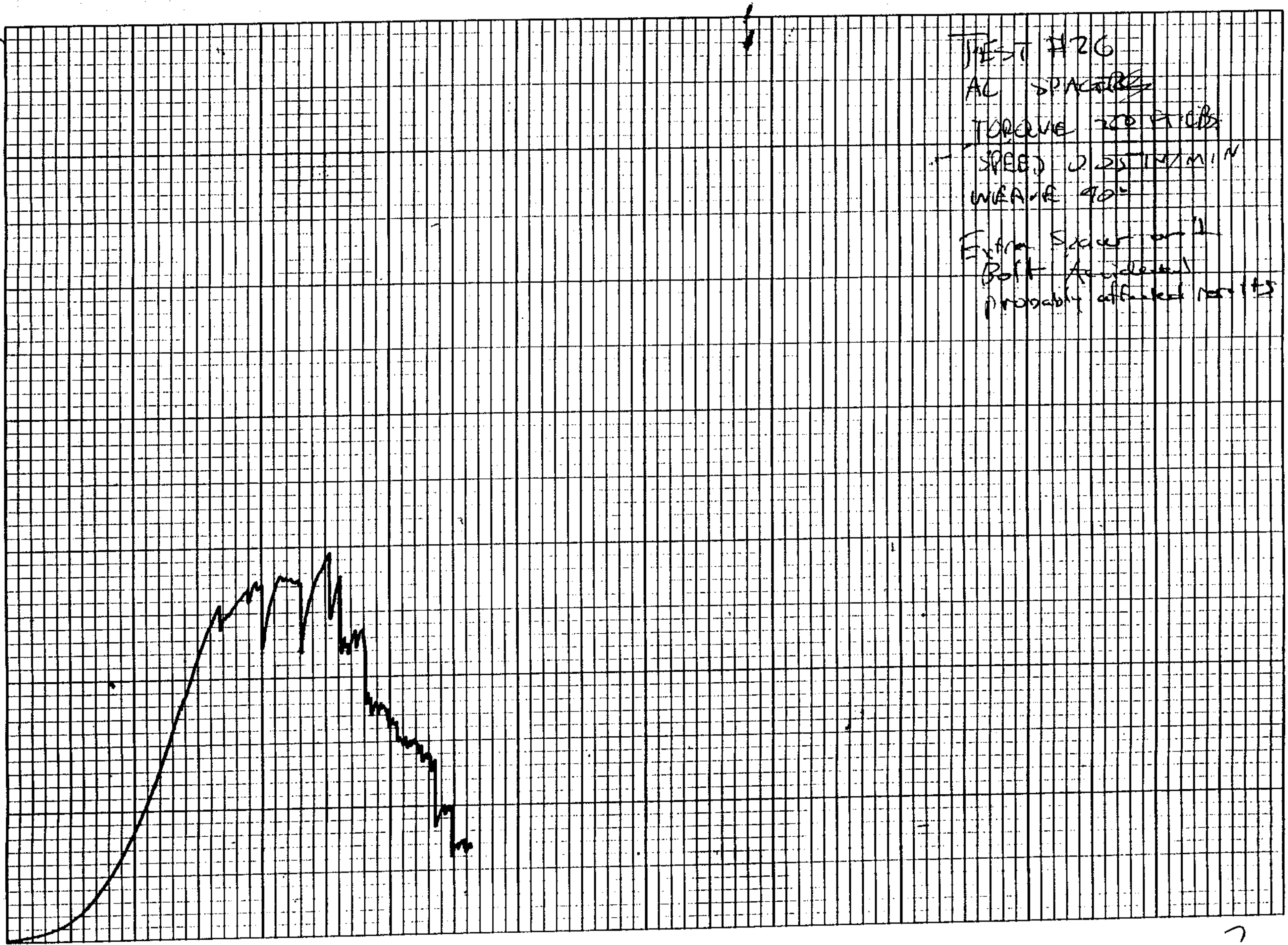
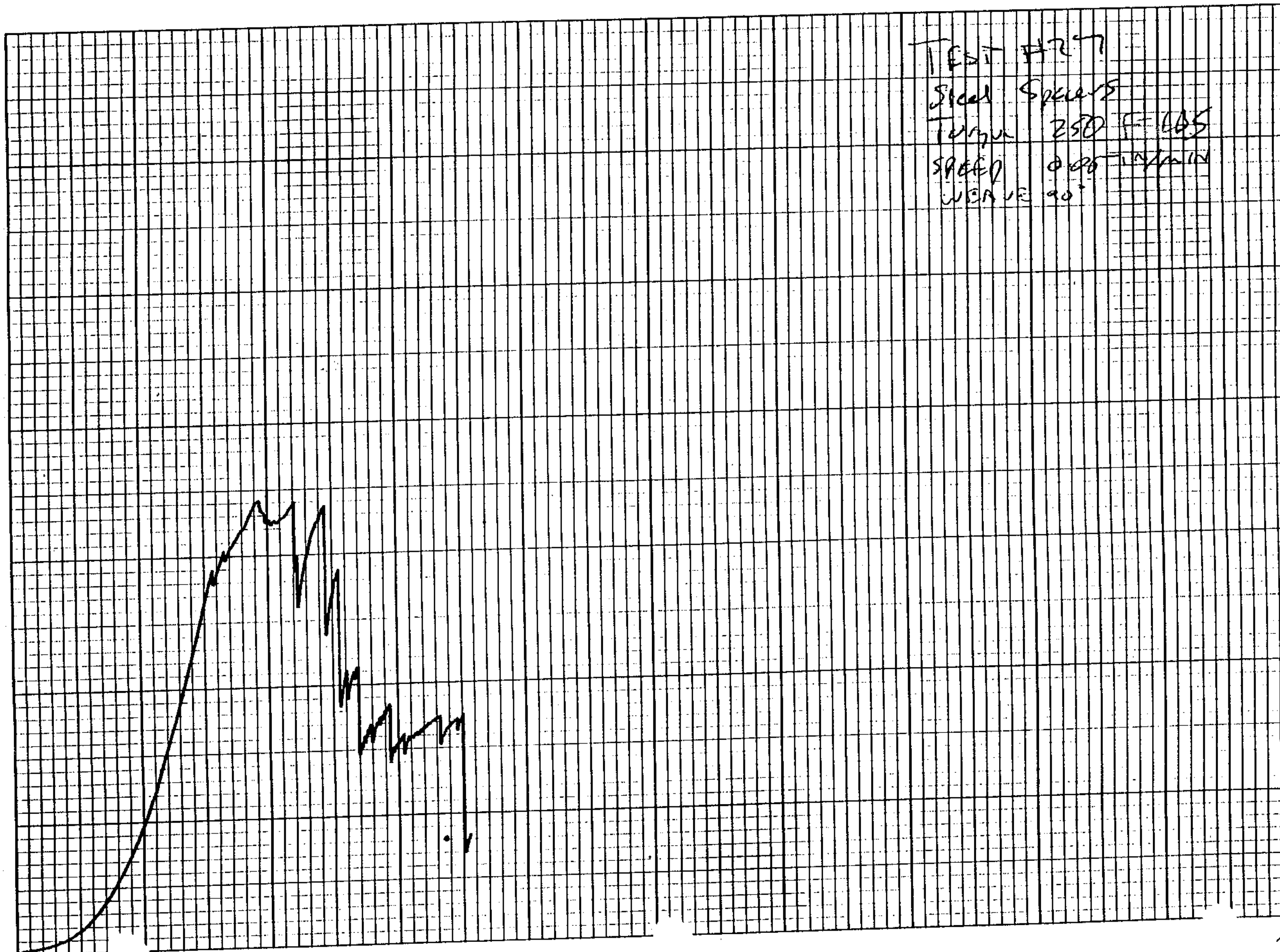



TEST 24
NO ALUMINUM
TORQUE 250 FT-LBS
SPEED 0.05 IN/MIN
WHAVE 40°

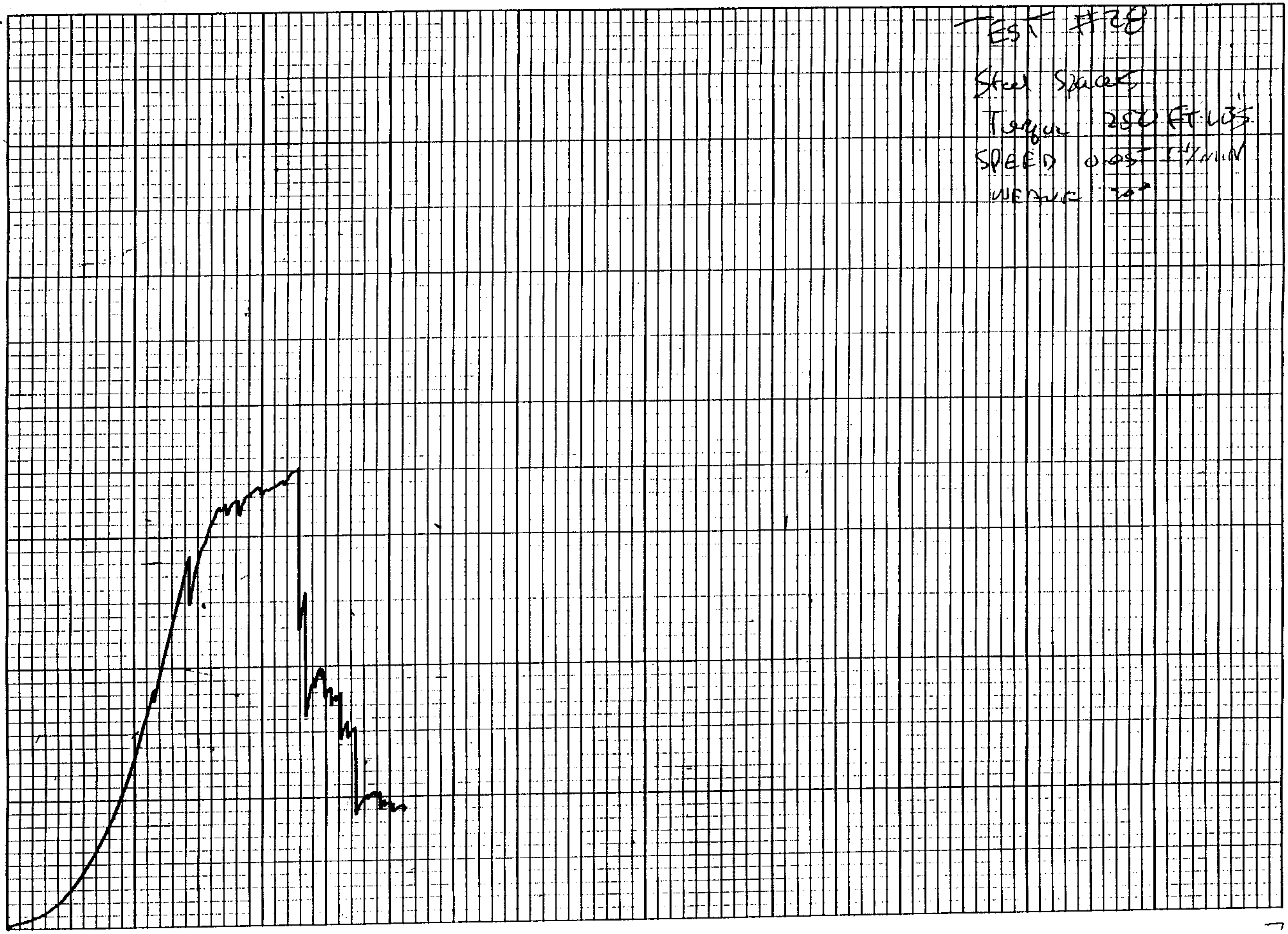

TEST #25
AL SPACERS - NEW
TORQUE 250 FT-LBS
SPEED 0.05 IN/MIN


TEST #26
AC SPACERS
TORQUE 200 FT-LBS
SPEED 0.25 IN/MIN
WEAR 40°
Extra Spacer on 1 Bolt Accidental
probably affected results


TEST #27
Steel Specers
Tempu 250 F 605
SPEED 0.05 IN/MIN
WEAVE 90°

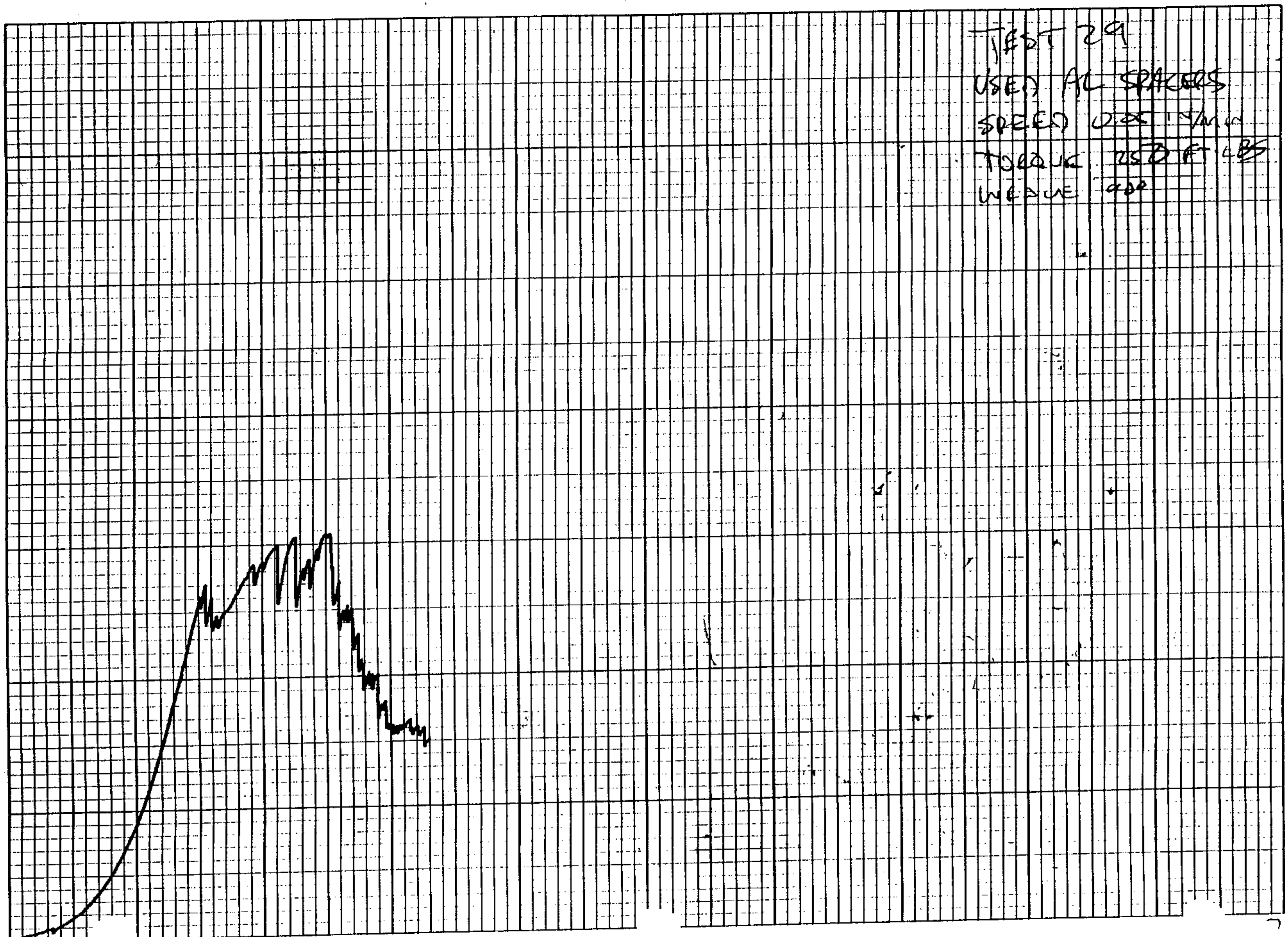
K•E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0780



K•E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0780



INCHES

Kevlar Window Tests Part II
KTev 1.8m Window

Frederick Renken
7/23/93
FNAL RD/MSD Mechanical Support Group

ABSTRACT:

A second series of tests was performed for the KTev 1.8m kevlar reinforced vacuum window. These tests were done to verify the results of previous tests (December 1992) and to find the effects of added epoxy and a different kevlar fabric manufacturer. The tests indicate that the bulkhead design and construction is sufficient to handle three times the operating pressure exerted during operating vacuum conditions. The addition of the epoxy dramatically improved the bulkhead performance and no significant differences in kevlar fabric could be noted. Some concerns remain over the validity of these tests but the window should perform at least as well or better than the tests indicate.

INTRODUCTION:

KTev, the new fixed target experiment at Fermilab, uses a large kevlar fabric reinforced mylar vacuum window. To verify the window meets safety and performance requirements a series of tests were performed using a clamping fixture prepared for a tensile test. The fixture was designed to simulate the bulkhead for a tension load. The results of these tests provided a bolt torque at which the bulkhead would be able to maintain a vacuum seal without damaging the mylar window material. The tests also verified which bulkhead construction and configuration would perform best. [RENK 1992] [SZYM 1993]

After the completion of tests in December 1992 it became necessary to perform another series of tests. These tests differed from the previous tests by the addition of epoxy to the test samples and a change in kevlar fabric manufacturer. The epoxy, used in all vacuum windows on site, was not used in previous tests because the cure requires 24 hours. This amount of time was neither available nor practical for the earlier tests. The second tests investigated the effects of the epoxy on both the load at first slip and the load at failure. A new fabric manufacturer was necessary because the old one could not supply a single sheet to cover the 1.8m window. Testing was performed in two orientations because the new fabric did not contain the same number of threads per inch in both weave directions. Finally, a new part was required for the Instron testing machine to safely test to the higher loads expected. Everything else, including bolt torque of 250 ft lbs and the clamping fixtures using aluminum o-rings, was the same for the second tests.

A:

r Test Data
Renken

ample	Orientation (vertical threads/inch)	First Slip (kips)	Max Load (kips)	Notes
	35	12.8	13.4	
	35	12.9	13.05	Test Curve Lost/Computer Failure
	35	11.9	11.99	Unusual Fail Pattern
	35	12.5	13.33	
	35	11.9	11.96	
	Average:	12.4	12.746	
	Deviation:	0.480	0.716	
	34	14.5	14.51	Almost Complete Fracture
	34	13.1	13.1	Sample made with "Tension"
	34	15.25	15.25	
	34	13.9	13.96	
	Average:	14.188	14.205	
	Deviation:	0.911	0.907	
s:	Average:	13.194	13.394	Desired is 13.094
	Deviation:	1.146	1.075	

ES:

.tation signifies the number of threads per inch sustaining the load or perpendicular to the ɔing fixtures. When one is looking at the sample. during the test. this is the number of ds running vertically. The kevlar fabric is supplied with 35 threads per inch in one direction n through 34 threads perpendicular.

desired load to sustain was calculated from an ANSYS analysis of the window [SZYM]. These calculations determined the load along a section of the bulkhead the same length · test sample for both vacuum conditions and for a safety factor of three. (Attached)

·sts were performed at a crosshead speed of 0.05 inches per minute complying with ASME e testing standards.

DISCUSSION OF DATA AND OBSERVATIONS:

Fraying was clearly evident on all samples. It was more prevalent in samples that fractured at lower values, especially around the bolt holes and epoxy region, . The test samples would fray along their edges during the entire test until failure. Fraying was also more significant on the samples with more threads in the pull direction. Fraying will not occur on the actual window because there are no free edges from which it can begin.

Effects of handling the samples during transportation and loading are indeterminate. The samples were prepared at Meson Assembly Building and then transported to the testing machine in the village. Since the testing clamps were somewhat heavy, loading samples into the machine was awkward and could have introduced failure points. Attempts to verify or control any effects were unsuccessful. Clearly the actual window will suffer no ill effects from handling and excessive transportation.

The data range is very high as indicated by the standard deviation. A high deviation leads to concerns over the validity of the tests. Engineering design and experience with existing windows should be considered along with these results. Furthermore, tests of the actual window will be the most accurate indicator of window performance.

The aluminum gaskets sustained similar deformation to previous tests. [RENK 1992]

Elongation of test samples approximately the same as previous tests. [RENK 1992]

Mylar remained undamaged, but reflected indentations from the aluminum o-ring.

CONCLUSIONS:

The 1.8m window should be able to sustain a 45 psig load. This is a safety factor of three over the operating conditions of the window (14.7 psia on vacuum). As attached calculations show, the force exerted in the x direction at 45 psig is 13,094 lbf which is below both the average first slip and failure values of 13194 lbf and 13394 lbf respectively.

The fabric appears to be stronger in the direction with fewer threads per inch. This is probably due to fraying which was more evident in the first tests performed with 35 threads per inch sustaining the load. Without fraying the fabric is most likely the same in any direction. The actual window, being circular and enclosed, will not have any fraying and so will be able to sustain higher loads than these tests indicate. Otherwise no differences in kevlar manufacturers can be determined from this test.

Failure patterns indicate uneven load distribution on the sample or the presence of weaker possibly damaged points. It was impossible to test distribution with the apparatus despite attempts to create an even load throughout a preloaded test sample (kev7). To construct the actual window, a plywood frame will be used to apply tension to the kevlar cloth to evenly and efficiently distribute it across the bulkhead. This was also done on the four foot window previously constructed.

The use of epoxy on the test samples dramatically increased the load at which first slip occurred. Without the epoxy, the average first slip occurred at 7062 lbf. The final failure value was also increased by the use of the epoxy. This is shown by the increase from 10670 lbf, without the epoxy, to 13394 with the epoxy. Additional epoxy placed around the bolt holes, as was done on previous windows, may continue to improve load values but not significantly.

REFERENCES:

[RENK 1992] Renken, Frederick. "Kevlar Window Tests" 12/23/93 unpublished, submitted to A. Szymulanski and J. Kilmer.

[SZYM 1993] Szymulanski, Andrew. "The 48 Inch Vacuum Window Component Inspection and its Impact on 1.8m Window Analysis." unpublished, a memo to J. Misek

LOAD CALCULATIONS FOR TEST CLAMPING FIXTURE:

A. Szymulanski 12/18/93

ANSYS: At 45 psig (Safety factor of 3)

T_x =296280 lbf: see Figure 1.

T_x per linear inch of the circumference:

$$T_{x_1} = \frac{296280}{\Pi(71)} = 1328.2 \quad \text{lb}$$

For a 9.858 inch wide fixture:

T_x = 13094

ANSYS: At 14.7 psia (vacuum operating conditions)

T_x =154880 lbf.

T_x per linear inch of the circumference:

$$T_{x_1} = \frac{154880}{\Pi(71)} = 694.36$$

For 9.858 wide fixture:

T_x = 6845 lbf

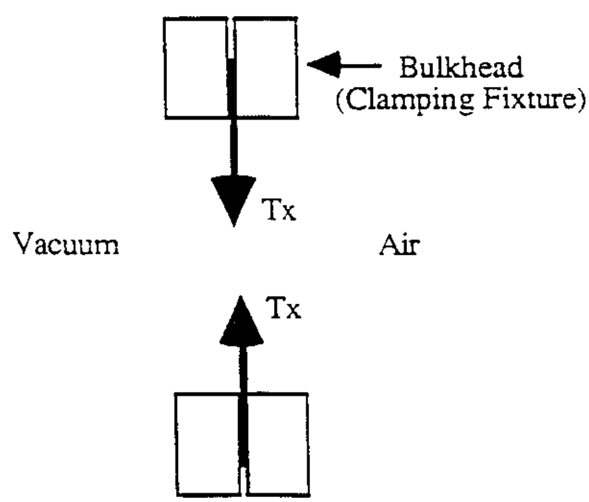
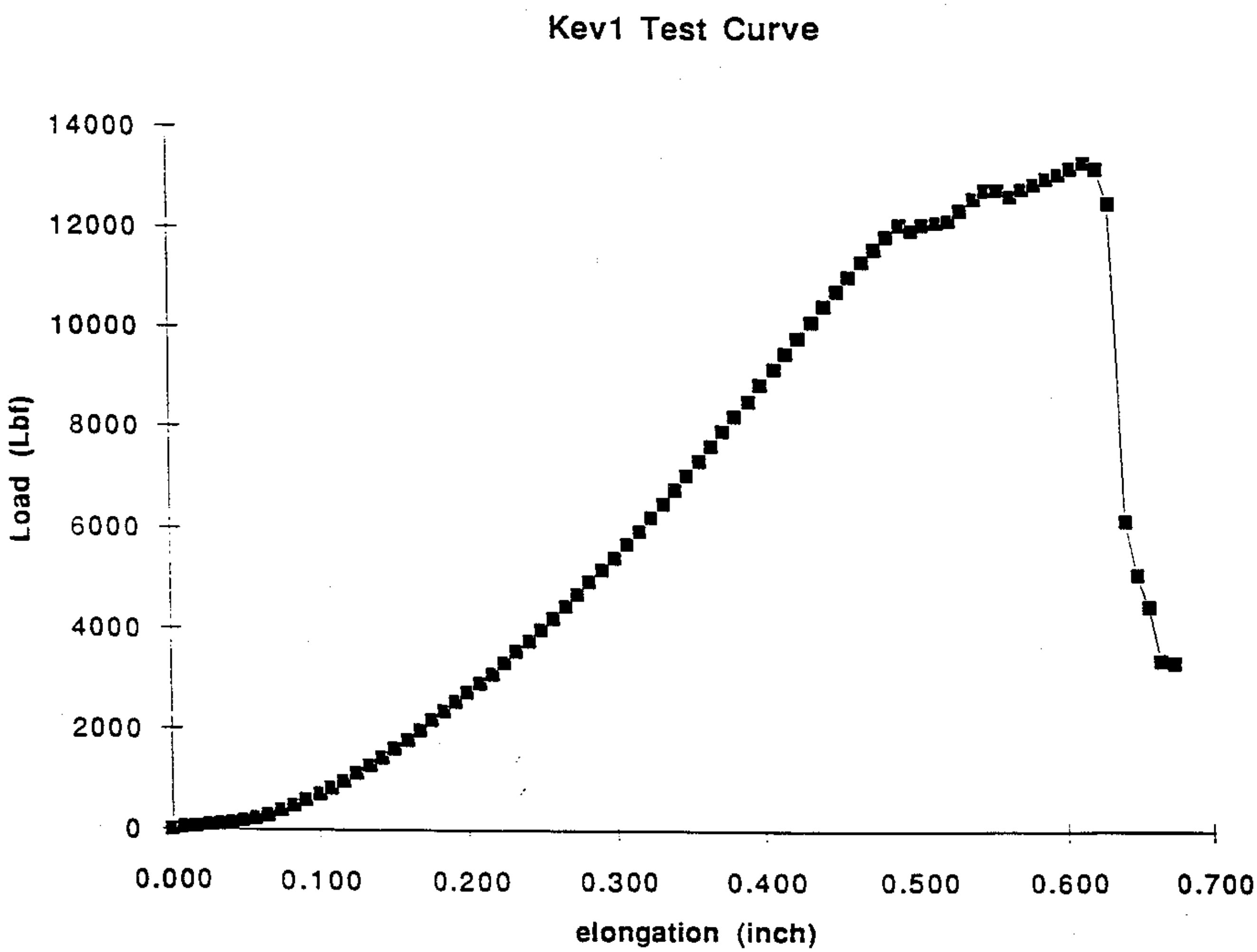


Figure 1: Cross Section of Bulkhead with force Tx exerted by fabric.

Kev1.6/30/93

	Fred Renken				
	30-Jun-93				
	Kevlar Test 1				
	Parallel count: 34				
	Perpendicular count: 35				
	Maximum Load 13.4 Kips				
	First Slip 12.8 kips				
	Standard Const—250 Ft•Lbs Torque				

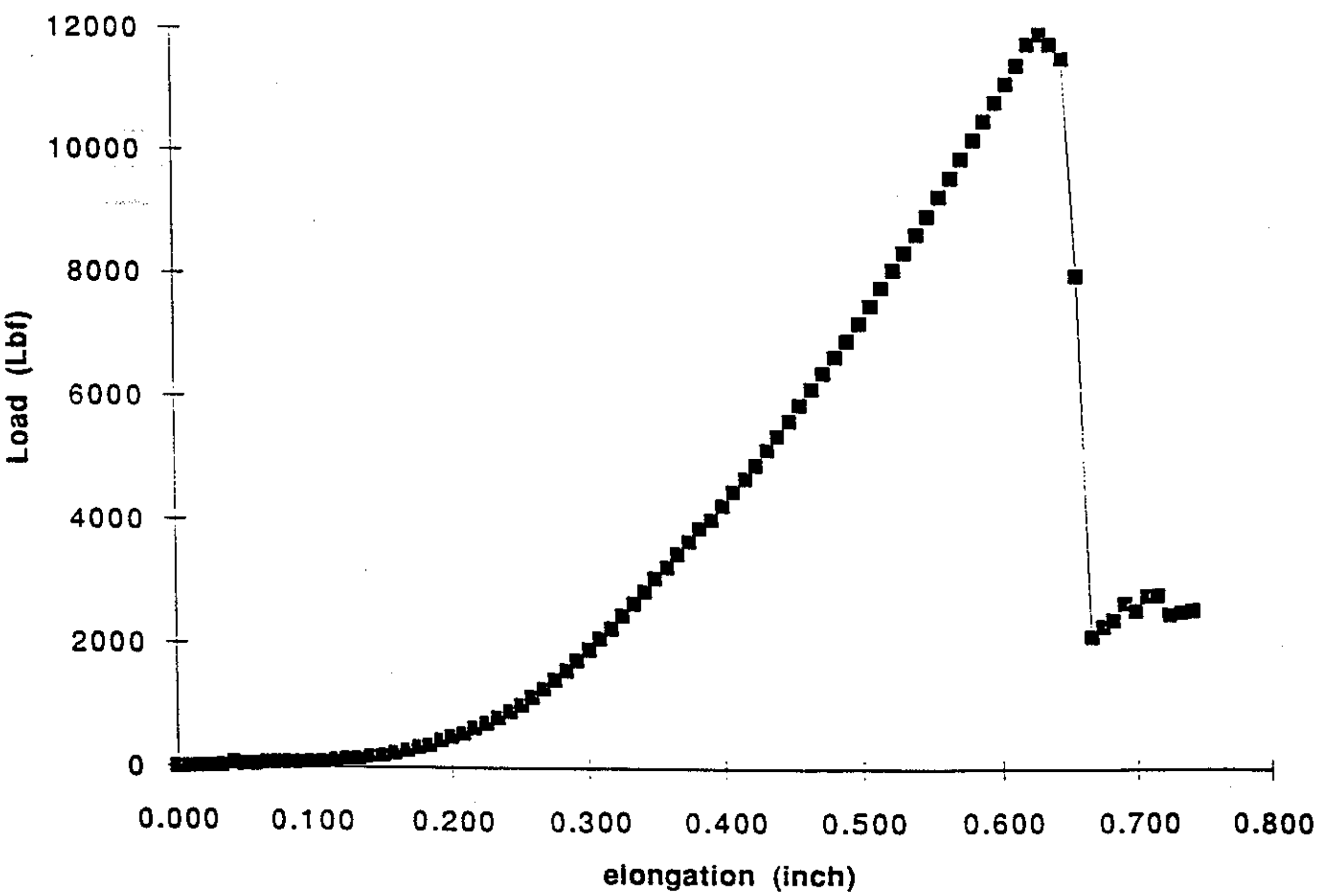


	Fred Renken					
	2-Jul-93					
	Kevlar Test 2					
	Parallel count: 34					
	Perpendicular count: 35					
	Maximum Load 13.05 Kips					
	First Slip 12.9 kips					
	Standard Const—250 Ft•Lbs Torque					
	Computer failure resulted in loss of data curve.					

Kev3.7/6/93

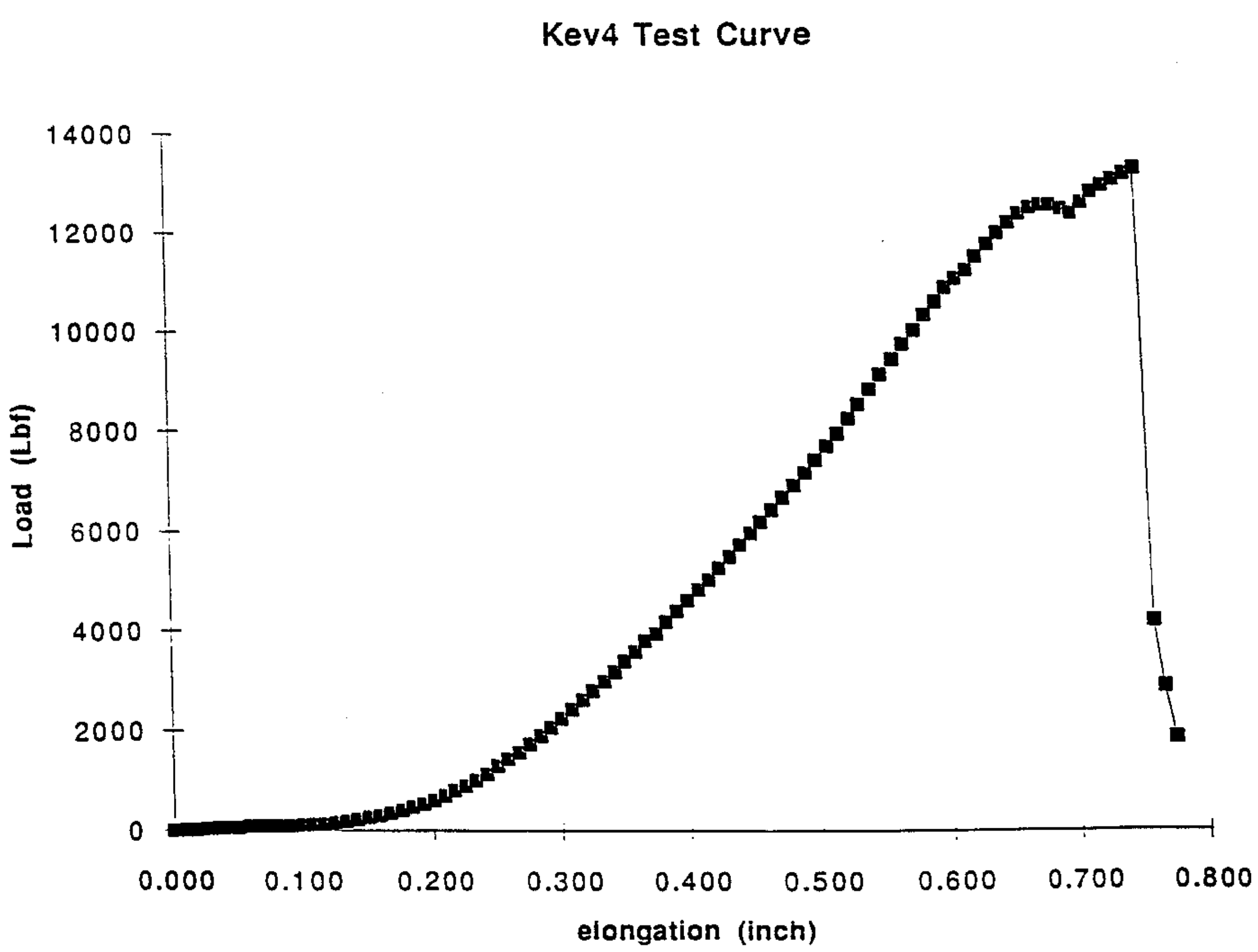
	Fred Renken				
	6-Jul-93				
	Kevlar Test 3				
	Parallel count: 34	Orientation to test fixture			
	Perpendicular count: 35				
	Maximum Load 11.99 Kips				
	First Slip 11.9 kips				
	Standard Const—250 Ft•Lbs Torque				

Kev3 Test Curve



Kev4.7/9/93

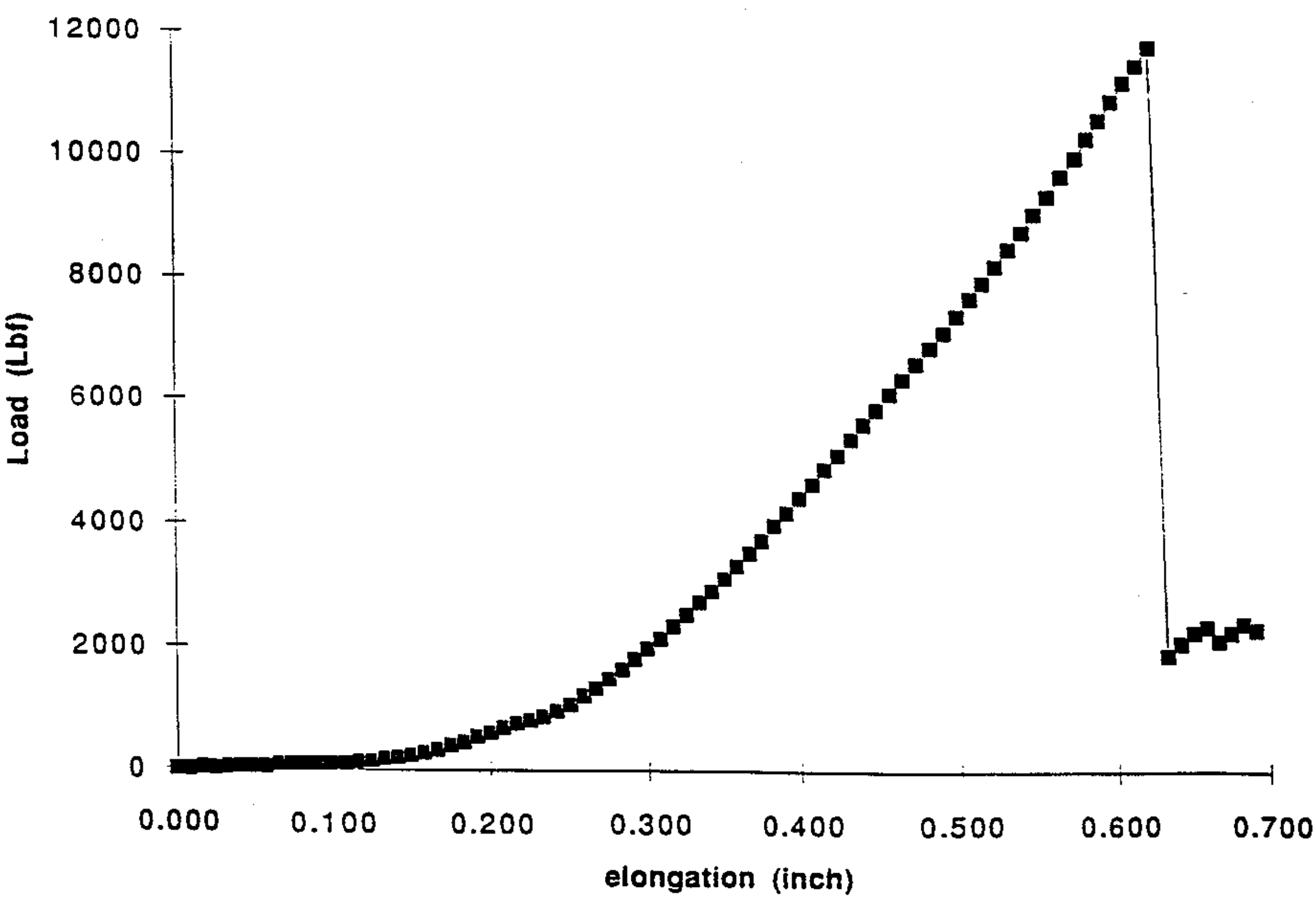
ion column	
	Fred Renken
	9-Jul-93
	Kevlar Test 4
	Parallel count: 34
	Perpendicular count: 35
	Maximum Load 13.33 Kips
	First Slip 12.5 kips
	Standard Const—250 Ft•Lbs Torque



Kev5.7/12/93

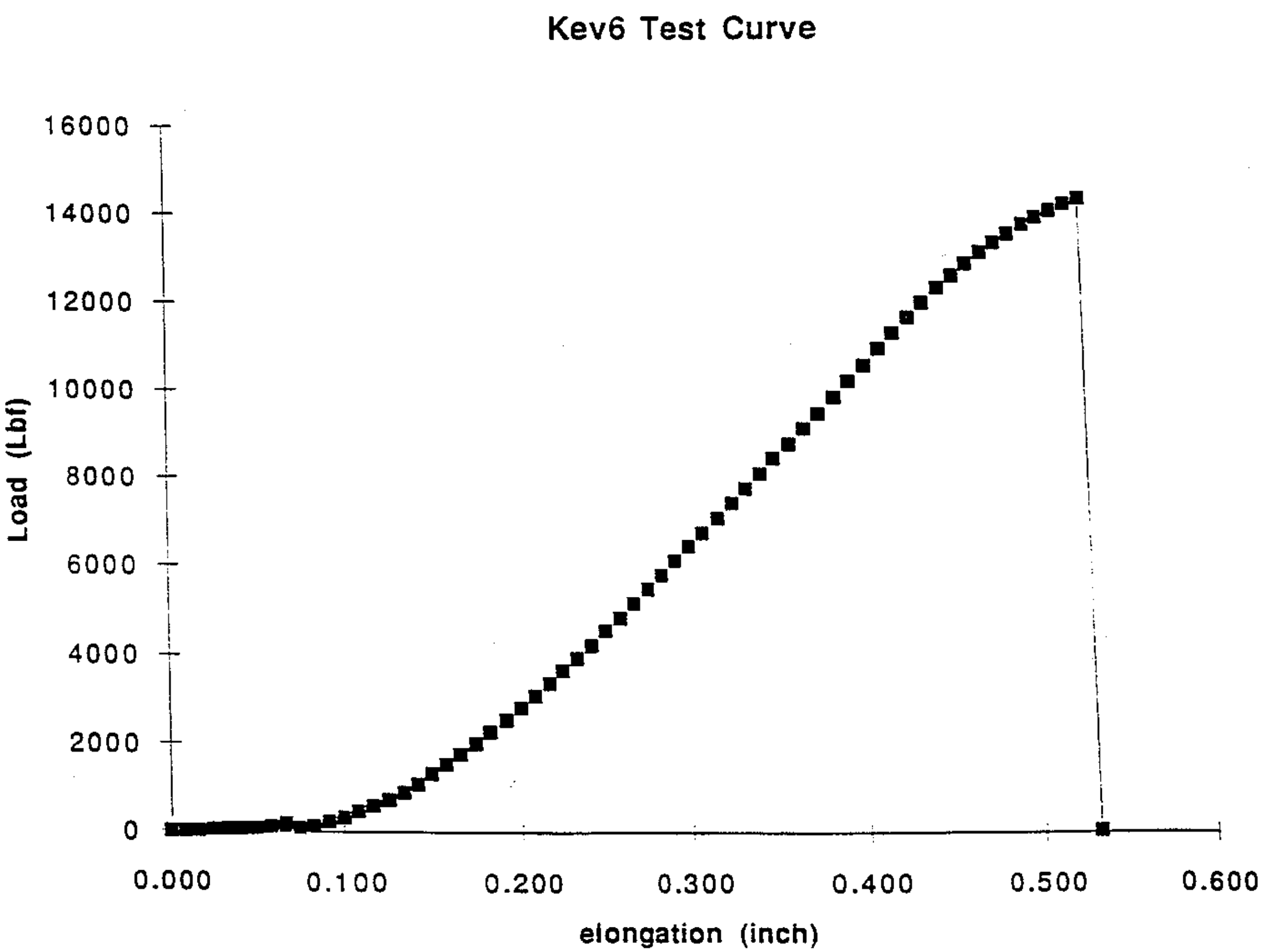
	Fred Renken				
	12-Jul-93				
	Kevlar Test 5				
	Parallel count: 34				
	Perpendicular count: 35				
	Maximum Load 11.96 Kips				
	First Slip 11.9 kips				
	Standard Const—250 Ft•Lbs Torque				

Kev5 Test Curve

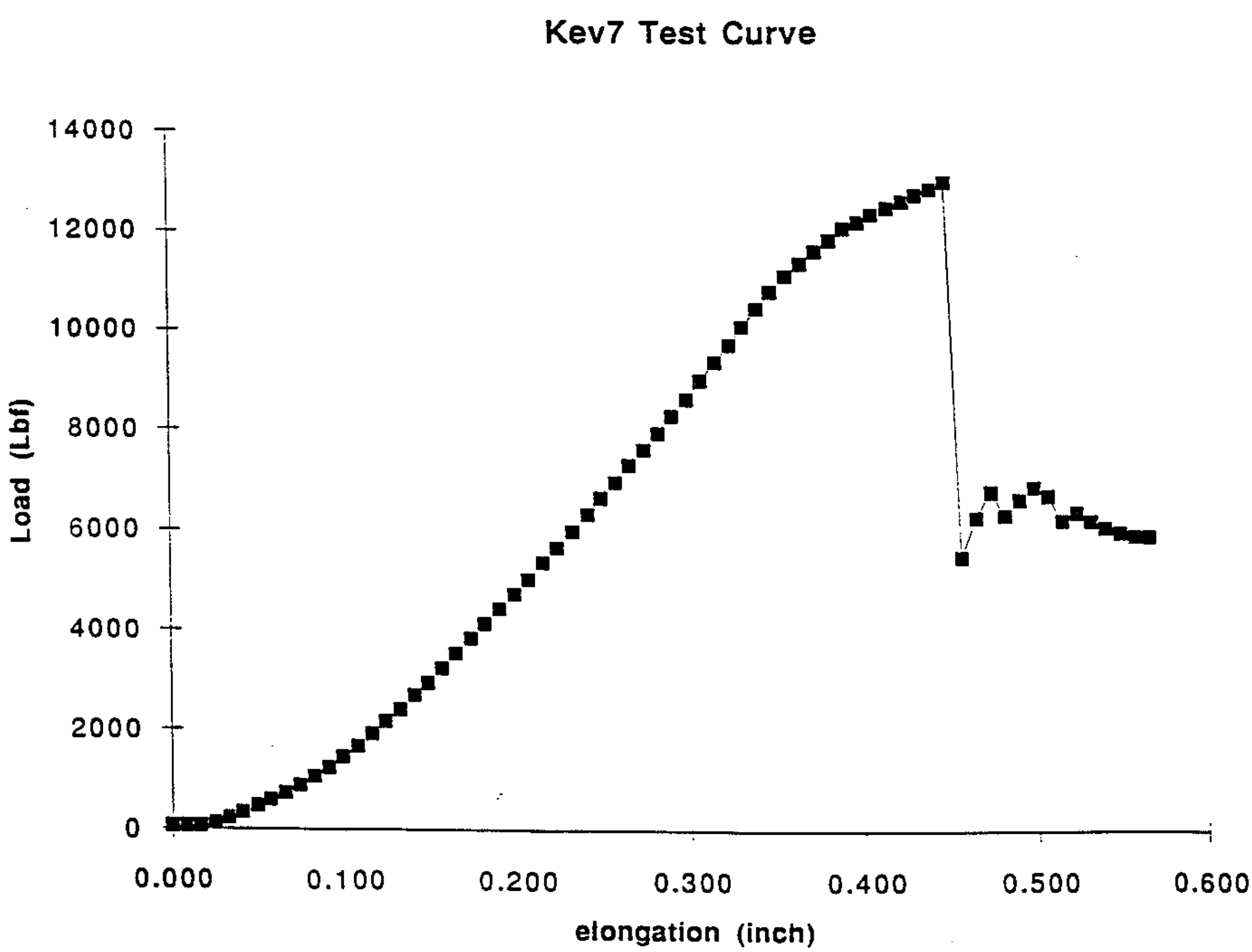


Kev6.7/14/93

	Fred Renken				
	14-Jul-93				
	Kevlar Test 6				
	Parallel count: 35				
	Perpendicular count: 34				
	Maximum Load 14.51 Kips				
	First Slip 14.5 kips				
	Standard Const—250 Ft•Lbs Torque				

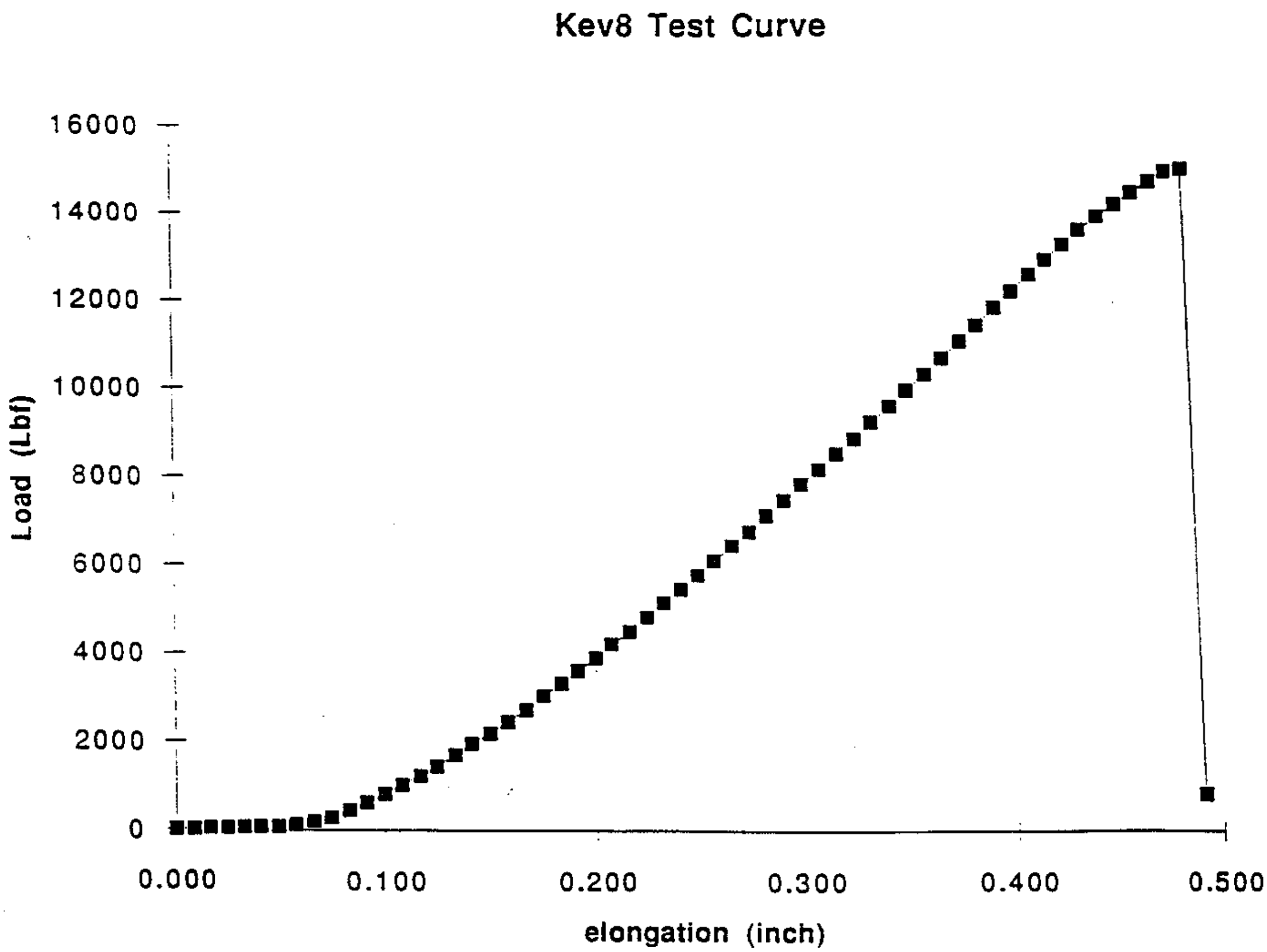


Fred Renken	
16-Jul-93	
Kevlar Test 7	
Parallel count: 35	
Perpendicular count: 34	
Maximum Load 13.1 Kips	
First Slip 13.1 kips	
Standard Const—250 Ft•Lbs Torque	



Kev8.7/19/93

	Fred Renken				
	19-Jul-93				
	Kevlar Test 8				
	Parallel count: 35				
	Perpendicular count: 34				
	Maximum Load 15.25 Kips				
	First Slip 15.25 kips				
	Standard Const—250 Ft•Lbs Torque				



Kev9.7/21/93

	Fred Renken
	21-Jul-93
	Kevlar Test 9
	Parallel count: 35
	Perpendicular count: 34
	Maximum Load 13.96 Kips
	First Slip 13.9 kips
	Standard Const—250 Ft•Lbs Torque